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W-63-R(SI)-35

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FINAL REPORT

W-63-R(SI)-35

ECOLOGY OF WHITE-TAILED DEER IN ILLINOIS

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Illinois Department of Conservation

August, 1992

Prepared by:

Alan Woolf, Director
Cooperative Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

Submitted by:

Alan Woolf, Director
Cooperative Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

John L. Roseberry, Senior Scientist
Cooperative Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

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Appendix B. Richards, B.J. 1992. Relationship between white-tailed deer distribution and habitat characteristics in Hamilton County, Illinois. M.S. Thesis, Southern Ill. Univ., Carbondale. 108pp.

Appendix C. Schulz, R. 1992. Estimates of population size and mortality of white-tailed deer in Hamilton County, Illinois. M.S. Thesis, Southern Ill. Univ., Carbondale. 113pp.

FINAL REPORT

STATE OF ILLINOIS

W-63-R(SI)-35, STUDY IV

Project Period: 1 July 1990 through 30 June 1992

Study IV: Ecology of white-tailed deer in Illinois

Prepared by Alan Woolf and John L. Roseberry
Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale

Need:

White-tailed deer management in Illinois has allowed expanded recreational use of the resource in response to an increasing deer population since the inception of the modern Firearms Season in 1957. Both the deer herd and recreational demand have grown steadily, but increases in the latter place growing pressure on the deer herd. More precise management is required to maintain recreational benefits without jeopardizing herd welfare. Specific information on behavior, biology, and ecology is needed on a herd and/or regional basis to implement sound management strategies.

Objectives:

1. To determine habitat utilization, activity patterns, and movements of deer living in semi-residential areas; and determine if these areas act as effective refuges and thus influence county deer quotas and current/ potential deer management strategies.
2. To estimate absolute size of a representative Illinois county deer population and identify/characterize all available deer habitat and measure its utilization.
3. To measure absolute annual harvest rates and assess non-hunting mortality factors to determine potential impact of harvest quotas on population size.
4. To determine the taxonomic status of regional Illinois deer herds.

EXECUTIVE SUMMARY

The objectives of this study were met by the completion of 3 Jobs this Segment. The study approach incorporated Objective 1 in Job A, Objectives 2 and 3 were integrated in Job B, and Objective 4 was met with Job C. Job D (Analyses and Report) has been accomplished with a series of quarterly and annual progress reports and this project completion report.

Objectives of Job A are reported in the form of a thesis prepared by Louis Cornicelli in partial fulfillment of the requirements for the Degree of Master of Science in the Department of Zoology at Southern Illinois University, Carbondale (SIUC). A summary of those findings is presented in the body of this report; the entire thesis is appended (Appendix A). Job B is reported in summary form in the body of this report; 2 theses prepared by Bryan Richards (Appendix B) and Richard Schulz (Appendix C) in partial fulfillment of the requirements for the Degree of Master of Science in the Department of Zoology at SIUC serve as the Job Completion reports. Job C is reported is the traditional manner. The report is a condensation of a Dissertation submitted by Dr. Jeffrey Levengood in partial fulfillment of the requirements for the Doctor of Philosophy degree at SIUC.

JOB A. Deer Habitat Utilization, Activity, and Movements

Objective: To determine habitat utilization, activity patterns, and movements of deer living in semi-residential areas; and to determine if these areas act as effective refuges influencing county deer quotas and management strategies.

SUMMARY OF FINDINGS AND CONCLUSIONS

1. A 4,669 ha study area was selected that included core urban, commercial, and residential locales within the city of Carbondale, Illinois, the SIUC campus, and properties on the outskirts that had an interspersion of residential development and deer habitat. The area was considered "typical" of a moderately sized community in a rural setting that has experienced a dramatic deer population increase during the past decade.
2. Habitat composition of the study area was 49.2% developed, 13.8% woods, 13.1% oldfield, 12.8% agriculture, and 11.1% grasses. Habitats available to deer consisted mainly of small blocks of woods and fields bordered by development.
3. An estimated 125-150 deer inhabited the Carbondale study area and formed 7 distinct herds. Some intermixing occurred between several groups during late-winter to early-spring, but generally the herds remained separated from one another. Herd densities ranged from 0.2 to 0.5 deer/ha. No overt signs of deer over-exploitation of habitat suggested that the population was lower than available habitat could support.
4. Home ranges of 12 radio-marked deer were up to 10 times smaller than reported for deer inhabiting rural habitats on nearby Crab Orchard NWR. Over all seasons, female home ranges averaged 39% smaller than those of males. Deer did not appear to

attempt to shift habitat use away from residential areas, rather they frequently used lawns and gardens as feeding sites. Activity budgets did not differ significantly from published values indicating that small home ranges met their biological needs without need to alter activity budgets or patterns.

5. Over 80% of residential survey respondents enjoyed the presence of deer with varying degrees of reservation; 44% had either seen deer or deer sign on their property. Although 83% of respondents preferred the population to stabilize or decrease, only 46% indicated they would support some type of regulated harvest.
6. The presence of deer in suburban communities such as Carbondale appears to be a relatively recent phenomena and suggests that management agencies should recognize suburban residents as a segment of the public (along with hunters and rural landowners) having direct contact and interest in deer.
7. Radio-marked deer had small home ranges and did not leave the study area thus the suburban study area served as a refuge since opportunity for legal hunting was limited. The distribution and size of such refuges within a county or region has potential to influence effectiveness of quotas designed to reduce deer abundance and consequences must be anticipated and planned for by managers.
8. Deer clearly have demonstrated ability to exploit suburban/residential habitats and become tolerant of human activities. Opportunities for hunting (or other forms of lethal population control) are limited at best in such situations. Inevitable deer-human confrontations will force wildlife managers to develop new strategies and management tools.

JOB B. Impact of Harvest Quotas on a County Deer Population

Objective: To estimate absolute size of a representative Illinois county deer population, to identify/characterize available habitat and use; and to estimate absolute annual harvest rates, non-hunting mortality, and the impact of harvest quotas on population size.

SUMMARY OF FINDINGS AND CONCLUSIONS

1. Hamilton County was selected as the primary study area. This county was relatively typical of the southcentral region of Illinois in terms of the amount of deer habitat and the recent history of apparent growth in size of the deer herd.
2. Habitat classification and analysis in Hamilton County revealed deer habitat to be more available than commonly thought and not shrinking rapidly. Habitat quality was rated in the counties' 432 sections; 50% was judged poor, 28% fair, and 22% good to excellent. Percent of forest in the county was 16-17%.
3. Legal harvest was the most important mortality factor of the Hamilton County deer herd and harvest rate of the female segment of the herd was by far the most important factor controlling herd size and growth.
4. The Hamilton County herd's growth performance over the past 30 years was very similar to that of Region 8 and the entire state. The observed pattern can be explained on the basis of female harvest rates. A decline in the rate of harvest of females in the early 1980's (apparently related to changes in hunter behavior and selectivity) resulted in a sharp population increase during the past decade. Habitat analyses demonstrated that an adequate habitat base existed to support the herd growth. Thus, herd increase

during the 1980's in the apparent face of increasing harvest pressure could be logically explained.

5. Current prehunt deer population size in Hamilton County is estimated to be 2,160 (range 1,900 - 2,400), or about 1.9 deer/km^2. Estimated current harvest rate is about 35% and there is some indication that herd growth is levelling off with harvest of about 20% of the female segment of the population.
6. Methods for evaluating harvest data described as useful by Roseberry and Woolf (1991. A comparative evaluation of techniques for analyzing white-tailed deer harvest data. Wildl. Monogr. 117, 1-59) also proved to be so for Hamilton County. In addition to population models, these less data-intensive methods should be incorporated into routine procedures for monitoring herd performance.
7. Using the same parameter values, independent population models developed by the Cooperative Wildlife Research Laboratory and the Illinois Natural History Survey staffs performed similarly. Both models could be combined and modified to be of greater use to managers.
8. Techniques developed during this study made it possible to classify townships in Hamilton County as having deer present at low, medium, or high density. Refinement of these techniques that use the tools of habitat analyses and Geographical Information Systems (GIS) and data sources now available make it feasible to classify, map, and evaluate deer habitat on a statewide basis.
9. Control of further herd growth (at any geographical level) will require proactive rather than reactive harvest strategies. It also will require strategies aimed at altering herd

composition rather than just thinking in terms of total numbers removed. This in turn will require greater use of predictive models and reliable methods of analyzing harvest data. Linking predictive population models with quantitative and qualitative habitat evaluation procedures offer managers a powerful tool to evaluate management scenarios and strategies.

JOB C. Taxonomic Status of Regional Illinois Deer Herds

Objective: To determine the taxonomic status of regional Illinois deer herds.

ABSTRACT

A total of 500 adult, female white-tailed deer (Odocoileus virginianus) skulls from the eastern and midwestern United States was examined to elucidate geographic patterns of morphological variation in this species, and to assess the subspecific status of regional Illinois deer herds. External measurements from 79 adult females from 3 regions of Illinois, and eviscerated mass of 55,335 individuals representing 6 age/sex classes from 79 counties were analyzed to further examine patterns of latitudinal variation in deer from Illinois.

The populations examined formed 2 groups, one characterized by larger animals from within the accepted range of O. v. borealis as well as northeastern Kansas and southeast Missouri, the other by smaller animals from within the range of O. v. virginianus and including Arkansas. These groups may be allocated to O. v. borealis and O. v. virginianus, respectively, given further study of character gradients across contact zones.

Although deer from southern Illinois were, on average, smaller than those from other regions of the state, results of multivariate and phenetic cluster analyses indicated that all of Illinois grouped with the large morphotype and should remain within the range of O. v. borealis. It is suggested that O. v. macrourus is a synonym of O. v. borealis, and that deer from Arkansas be allocated to O. v. virginianus. Results indicated a wide range of variation in skull characteristics, and a relatively large size component to this variation. Analysis of skull shape contrasts suggested greatest separation of those groups with the most divergent genetic background, based upon the current geographic distance between some groups and the history of relocations of others. Contemporary populations may have retained characteristics of stock introduced into these areas.

Patterns of morphological variation detected in this study indicated that on a broad geographic scale, deer are responding to widespread, generalized selection pressures and conform to Bergmann's Rule. Adaptive shifts in size may occur in response to local or regional variation in selective forces, producing regional exceptions to Bergmann's Rule. Within Illinois, a curvilinear relationship existed between latitude and deer carcass mass. Regional patterns of variation in the relationship between mass and latitude, soil fertility, percentage of county forested, and hunter success (density) were apparent. Latitude contributed most to this variation on a regional level. The relationship between mass, latitude, climate, and environmental quality (soil fertility, land-use, density) indicated that mass was related to regional variation in climate, and that the effects of environmental quality were superimposed upon this pattern. Some demographic groups may respond differently to the environmental pressures impinging upon them.

INTRODUCTION

White-tailed deer (Odocoileus virginianus) were extirpated from large areas of the northeastern and midwestern United States by the end of the nineteenth century (Halls 1978; Hamilton and Whitaker 1979; McCabe and McCabe 1984). Indiscriminate killing by market and subsistence hunters, cutting and subsequent burning of virgin forests, and competition with cattle led to the extermination of white-tailed deer from much of their historical range. Deer were virtually eliminated from Illinois by the early 20th century, the last reported sightings coming from southern Illinois around 1910 (Pietsch 1954; Calhoun and Loomis 1974). White-tailed deer began to reappear in Illinois during the 1930s, due to improved habitat conditions, game laws, and restocking programs (Halls 1978).

The reintroduction of deer into Illinois began in the 1930s with animals from Michigan and Wisconsin, and others of unknown origin (Pietsch 1954). Reintroductions with animals of differing stock, game farm escapes, natural emigration, and the possibility of surviving remnants of the original herds have obscured the taxonomic picture of deer in Illinois as well as other regions (Kellogg 1956; Halls 1978; Smith et al. 1984).

Biologists traditionally have included Illinois within the range of the large northern woodland white-tailed deer (O. v. borealis Miller), with another large form, the Kansas white-tailed deer (O. v. macrourus [Rafinesque]), occurring in the central plains states west of the Mississippi River, and a smaller race, the Virginia white-tailed deer (O. v. virginianus [Zimmerman]), found southeast of the Ohio River (Kellogg 1956; Whitehead 1976; Halls 1978; Hall 1981) (Fig. 1).

Zimmerman (1780) is credited with being the first to formally name the Virginia or white-tailed deer, *Dama virginiana* (= *Odocoileus virginianus*), based partly on Ray's (1693) description of a specimen from Virginia. In 1817, Rafinesque named a new species of deer (*Corvus macrourus*) found on the plains west of the Mississippi River, based on a description from the journal of Charles LeRaye. Rafinesque (1817) gives the locality as the plains near the Kanzas River; Hall and Kelson (1959) interpreted this as the plains near Wakarusa Creek, Douglas County, Kansas.

Mearns (1898:26) characterized *O. v. macrourus* as "a large pallid form of the northern plains region". Allen (1901) named a new subspecies, the "Louisiana deer" (*O. v. louisianae*), based on specimens from Morehouse County, Louisiana. Allen (1901) distinguished *O. v. louisianae* from *O. v. virginianus* based on the former's larger size and proportions, and from *O. v. borealis* on the basis of cranial, dental, antler, and pelage characteristics. Subsequently, Allen (1902) maintained the distinction between *O. v. louisianae* and *O. v. macrourus*, it's neighbor to the north, by listing the two as separate forms.

Barbour and Allen (1922) suggested the need for further investigation into the taxonomic relationship between *O. v. louisianae* and *O. v. macrourus*. Miller (1928) named a smaller race, the Avery Island white-tailed deer (*O. v. mcilhennyi*), from the lowlands of coastal Louisiana, distinguishing it from *O. v. louisianae* by the former's smaller size and reduced nasal and premaxilla bones. In his revision of *Odocoileus virginianus* Kellogg (1956) maintained the subspecific status of *O. v. mcilhennyi*, dropped *O. v. louisianae*, and included the northern two-thirds of Louisiana within the range of *O. v. macrourus* (Fig. 1).

Subsequent authors have maintained this classification (Hall and Kelson 1959; Halls 1978; Hall 1981; Baker 1984).

Miller (1900) described a new race of *O. virginianus*, the Northern Virginia (= northern woodland white-tailed) deer (*O. v. borealis*), from the northeastern United States and southeastern Canada. He differentiated *O. v. borealis* on the basis of it's large size, long lower molar tooth row, distinct winter pelage, and stout antlers (relative to *O. v. virginianus*). Although Barbour and Allen (1922) maintained the distinction between *O. v. borealis* and *O. v. virginianus*, the authors considered *O. v. borealis* a poorly marked subspecies. Kellogg (1956) extended the range of *O. v. borealis* south to the Potomac and Ohio Rivers and west to the Mississippi River (Fig. 1).

Although electrophoretic studies have generally failed to discriminate between parapatric subspecies, it seems plausible that the mixing of genetic stocks through reintroductions and the high genetic variation inherent in this species have combined to confound genetic discrimination of some subspecies (Smith et al. 1984). Smith et al. (1984:121) suggested that "differences among white-tail populations throughout the species' range may have genetic constraints, whereby the races or subspecies are restricted within various physiological/morphological amplitudes".

While some authors have criticized the subspecies concept and its usefulness (Wilson and Brown 1953; Brown and Wilson 1954), others have defended the trinomen as a valuable heuristic tool used to identify and describe geographically varying segments of a species population (Durrant 1955; Smith and White 1956; Tilden 1961; Johnson 1982; Mayr 1982; Monroe 1982; O'Neill 1982). Some biologists have argued that properly-identified subspecies are real biological entities, or incipient species (Darwin 1859; Monroe 1982; O'Neill 1982; Smith 1967; Whitaker 1970). Most proponents, however, agree with the need for stricter standards for recognizing subspecies.

Ritchie (1970) compared deer from northern and southern Illinois and found that the latter exhibited smaller masses and basal antler beam diameters than the former. He believed these differences resulted from southern deer surviving on a lower nutritional plane. Harder (1980) compared the relationship between body mass and reproductive rates among several populations from the northern United States and found that, with one exception, populations with high female body mass had high reproductive rates. Deer from Crab Orchard National Wildlife Refuge in southern Illinois had high fetal rates albeit low body mass. Nelson and Woolf (1985) suggested that these differences in size may reflect genetic differences, based on the high productivity and good physical condition of deer on Crab Orchard National Wildlife Refuge (Roseberry and Klimstra 1970; Nelson 1984).

The need to clarify the taxonomic status of Illinois deer has management implications. Physical characteristics such as eviscerated and whole body mass, chest girth, hind foot length, and antler development of selected age classes may be used as indicators of habitat quality and relative density with respect to carrying capacity. Thus, taxonomic status of regional Illinois deer herds must be established before spatial and temporal variation in these condition indices can be properly evaluated.

The objectives of this study were 1) to examine geographic patterns of morphological variation in white-tailed deer from the eastern and midwestern United States, 2) to assess the subspecific status of regional Illinois deer herds, 3) to examine patterns of latitudinal variation in eviscerated weights of adult, female deer from Illinois, and 4) to test the hypothesis that deer from southern Illinois are assignable to the nominal O. v. virginianus.

METHODS AND MATERIALS

Crania

Collections.-- A total of 500 adult, female white-tailed deer skulls were examined (Table 1). Most skulls were collected from hunter-harvested animals, however museum specimens were also examined when available. Females were chosen because hunters are more likely to donate the heads of does than bucks. Also, females attain maximum size earlier in life than males (Crawford 1962; Teer et al. 1965; Ludwig 1967; Roseberry and Klimstra 1975). Thus, restricting analyses to adult females reduced the effects of age-related variation, and removed the effects of secondary-sexual variation.

Initial collections from Illinois included northwestern (Carrol, Jo Daviess, and Whiteside counties), westcentral (Adams and Pike counties), and southern (Alexander and Williamson counties) regions of the state (Fig. 2). These areas are characterized by rolling to rugged uplands dissected by forested stream and river corridors, and tracts of contiguous forested habitat. Preliminary sampling also included the prairie region of eastcentral Illinois (Dewitt, Livingston, McLean, and Piatt counties), an area distinctly different with respect to habitat, land-use, and physiography. This region is characterized by flat, intensively-farmed terrain with isolated forest habitats. Subsequent collections included southcentral Illinois

(Jefferson and Washington counties) and Effingham county, in order to examine for clinal variation between central and southern Illinois (Fig. 2).

Crania from geographically disjunct areas within the accepted range (excluding Illinois) of O. v. borealis, O. v. macrourus, and O. v. virginianus were examined (Fig. 1). These included: for O. v. borealis, northeastern Minnesota, southcentral Michigan, southwestern Pennsylvania, and southern Maine (type locality Bucksport, Hancock Co.); for O. v. macrourus, northeastern Kansas (type locality near Wakarusa Creek, Douglas Co.), Arkansas (primarily northcentral), and southeastern Missouri; for O. v. virginianus, eastcentral and westcentral Virginia (type locality Virginia), southwestern South Carolina and southwestern Tennessee. More detailed information on sampling localities is provided in Appendix A.

Measurements.-- Ages of specimens were determined according to tooth eruption and wear (Severinghaus 1949). Cleaned and dried crania and rami were measured with a Helios dial micrometer (0.05 mm calibration) and a Dunlap measuring board (1.0 mm calibration). A series of 20 measurements were taken from each skull, and are described below. Right-handed measurements were taken when possible. All measurements except CRANBD, CRANHT, and M2M2 are after Rees (1969a), McCain (1970), and Deblase and Martin (1981). CRANBD and M2M2 are described in Kirkland and Van Deusen (1979); CRANHT is from van Zyll de Jong (1980).

Greatest length of skull (GREATLEN) - from anterior edge of premaxillae to posteriormost point on skull.

Condylobasal length (CONDYLO) - from anterior edge of premaxillae to posteriormost edge of occipital condyles.

Nasal length (NASALEN) - greatest anterio-posterior length of nasals.

Least nasal width (NASALWID) - narrowest width across nasals.

Rostral breadth (ROSTRAL) - greatest breadth of rostrum measured through a line extending ventrally from the posteriormost edge of the premaxillary-maxillary suture.

Least interorbital width (INTER) - narrowest width between the orbits.

Cranial breadth (CRANBD) - greatest width of braincase measured across the squamosals.

Cranial height (CRANHT) - greatest height of braincase measured vertically from the basisphenoid to the juncture of the fronto-parietal sutures.

Upper PM2-M3 (UPM2M3) - length upper molariform tooth row, measured at the tarter line.

Lower PM2-M3 (LPM2M3) - length lower molariform tooth row, measured at the tarter line.

Width across M2-M2 (M2M2) - distance between the lateral edges of M2 at the posterior lateral margin of tooth.

Diastema length (DIASTEMA) - posterior margin alveolus of the canine to anterior margin alveolus of first premolar (PM2).

Zygomatic width (ZYGOMA) - greatest width across zygomatic arches.

Palatal length (PALATLEN) - anterior edge of premaxillae to staphylion (staphylion is defined as the point at which a line tangential to the two curves in the posterior border of the palate crosses the midline).

Palate width (PALATWID) - least width of palate.

Incisive foramen (INCISIVE) - greatest length anterior palatal foramen.

Postpalatal length (POSTPAL) - anterior rim foramen magnum to staphylion.

Condylar width (CONDYLAR) - distance between lateral borders of occipital condyles.

Mandible length (MANDLEN) - greatest length of ramus.

Mandible height (MANDHT) - vertical distance from base of mandible to tip of coronoid process.

External Characters

Collections.-- A series of six external measurements were taken from hunter-harvested animals at check stations located in northwestern (N= 22), westcentral (N= 27), and southern (N= 30) Illinois (Fig. 2).

Measurements.-- These measurements are described below and all except metatarsal gland are after Deblase and Martin (1981) and Brisbin and Lenarz (1984).

Total length (TOTLEN) - tip of the nose to distal end of the last caudal vertebra, measured along the curvature of the spine.

Tail length (TAIL) - base of tail to distal end of last caudal vertebra.

Hind foot length (FOOT) - point of hock to tip of hoof.

Ear length (EAR) - notch at base of ear to edge of pinna.

Height at shoulder (SHOULDER) - perpendicular distance from withers to tip of hoof, with leg extended.

Metatarsal length (METATARS) - length of external keratinized patch.

Mass Data Collection

Eviscerated mass data were recorded at hunter check stations throughout Illinois. Seventy-nine counties and the following years were represented: 1969-1972, 1979, 1982-1985. Deer were aged, sexed, and weighed by check station personnel. County means by age/sex class represent a total of 55,335 individuals.

Data Analysis

Skeletal.-- Evaluations of univariate and multivariate normality, outliers, and homogeneity of variance-covariance matrices were satisfactory. Specimens were grouped by geographic region. An alpha level of $P<0.01$ was selected for univariate and multivariate analyses of skeletal characters. Testing for differences between means was accomplished using the GLM procedure of SAS (SAS Institute Inc. 1985a); multiple comparisons were performed using the Tukey/Kramer method. Nonparametric comparisons were accomplished using the Kruskal-Wallis Chi-square approximation, available through the NPAR1WAY procedure of SAS (SAS Institute Inc. 1985a).

Stepwise discriminant function and canonical-variates analyses were used to identify and separate groups, and were performed using the DISCRIMINANT procedure of SPSSX (SPSSX Inc. 1983). Stepping was accomplished using the MAHAL specification of the METHOD subcommand. This procedure selects a subset of the original variables which maximizes Mahalonabis' distance between the two closest groups. F-to-enter and F-to-remove were set at the default value of 1.0. Prior probabilities were set equal to sample sizes to account for disparity in group size.

A principal component analysis was used to examine with-in group variation and to examine relationships between variables. Principal components were factored from the covariance matrix of morphometric characters as suggested by Bookstein et al. (1985). The second and third component were sheared to remove the overall size effects (Humphries et al. 1981), using a program designed by D. L. Swofford of the Illinois Natural History Survey. A distance phenogram was constructed based on a UPGMA analysis of standardized character means using CLUSTER and TREE of SAS (SAS Institute, Inc 1985a).

Eviscerated Mass.-- Data were analyzed using the REG, CORR, GLM, and MEANS procedures of SAS (SAS Institute, Inc. 1985a). An alpha level of $P < 0.05$ was selected for analyses of variation in eviscerated mass. Illinois maps were constructed using the GMAP procedure of SAS/GRAPH (SAS Institute, Inc. 1985b). Testing for normality revealed slight to moderate skewness for all variables except latitude and hunter success. Transforming variables increased skewness, so original variables were used.

RESULTS

Subspecific Comparisons

Odocoileus virginianus borealis.-- Univariate comparisons of adult female O. v. borealis from Pennsylvania, Maine, Michigan, and Minnesota revealed 8 cranial characters that exhibited significant levels of geographic variability (Table 2). Specimens from Pennsylvania averaged significantly smaller than those from Minnesota, Michigan, and Maine for 7, 2, 1, of the 8 characters exhibiting geographic variability, respectively. Although skulls from Minnesota averaged larger than those from Pennsylvania, Maine, and Michigan for 17 of 20 measurements, these differences were significant only for M2M2, CONDYLAR, and MANDHT.

Ten cranial characters exhibited clinal variation for size consistent with Bergmann's Rule, beginning in southwestern Pennsylvania and progressing northward through southcentral Michigan, southcentral Maine, and ultimately northeastern Minnesota (Table 2). Three additional measurements exhibited this trend of increasing size with latitude through

Maine; Minnesota specimens were intermediate between Michigan and Maine for NASALWID and INTER, and equal to specimens from Michigan for INCISIVE.

A stepwise discriminant function analysis was performed using 20 cranial measurements from 71 specimens as predictors of membership in 4 groups (defined in Fig. 3). Three functions were derived, however, after removal of the first two functions, no significant discriminatory power remained ($X^2_{11}=19.8$, $\underline{P}=0.05$). The first and second functions accounted for 51 and 35 percent of the between-group variability, respectively.

Thirteen characters in combination were found to be useful in discriminating between groups. Based on standardized discriminant function coefficients CONDYLO (-4.0), PALATLEN (3.0), and POSTPAL (1.7) were among the most important discriminators on the first function; CONDYLO (2.1) and PALATLEN (-1.6) were the primary distinguishing variables on the second function. A bivariate plot of canonical-variates scores revealed considerable overlap between samples from Michigan and Maine (Fig. 3). The samples from Pennsylvania and Minnesota were separated from Maine on the first function, and from each other on the second function. Specimens from Pennsylvania clustered just peripheral to the Michigan polygon, while the Minnesota and Michigan polygons overlapped to a large degree.

Fifty-nine (83%) specimens of the O. v. borealis group were correctly classified as to region of origin. Fourteen (87.5%), 26 (86.7%), 12 (75.0%), and 7 (77.8%) specimens from Pennsylvania, Michigan, Maine, and Minnesota were correctly classified, respectively. Of 12 misclassed individuals, 6 involved misclassifications between Michigan and Maine.

Odocoileus virginianus macrourus.-- Univariate comparisons of O. v. macrourus from Arkansas, Missouri, and Kansas revealed 17 characters which varied significantly among regions (Table 3). Mean values for NASALEN, PALATWID, and DIASTEMA did not differ between regions. Specimens from Arkansas averaged significantly smaller than those from Kansas for 16 of 17 geographically-variable cranial characters (INCISIVE excepted), and smaller than Missouri specimens for 6 of these measurements. Specimens from Missouri averaged smaller for 9 of 17 measurements, when compared to skulls from Kansas (Table 3).

Sixteen characters exhibited clinal variation for size consistent with Bergmann's Rule, beginning in Arkansas and progressing northward through Missouri and Kansas (Table 3). This trend was significant across all 3 groups for M2M2 and MANDHT.

A stepwise discriminant function analysis was performed using 20 cranial measurements from 65 individuals as predictors of membership in 3 groups (defined in Fig. 4). Two functions were derived, with a combined $X^2_{32}=132.8$, $\underline{P}<0.001$. Both functions contributed significantly to overall discriminating power. The first and second functions accounted for 60 and 40 percent of the between-group variability, respectively.

Sixteen cranial characters in combination were found to be useful in discriminating between groups. CONDYLO (2.8), GREATLEN (-1.9), PALATLEN (-1.4), DIASTEMA (-1.4), and POSTPAL (-1.0) were important discriminators on the first function; PALATLEN (-1.4), CONDYLO (2.8), and POSTPAL (-1.0) were primary distinguishing variables on the second function.

A bivariate plot of canonical-variates scores revealed the samples from Arkansas, Missouri, and Kansas to be virtually distinct (Fig. 4). The Arkansas and Missouri polygons overlapped slightly, due to the misclassification of 1 Missouri specimen.

Sixty-four (98.5 %) specimens of the O. v. macrourus group were correctly classified as to region of origin. One skull from Missouri was grouped with Arkansas specimens.

Odocoileus virginianus virginianus.-- Comparisons of O. v. virginianus skulls revealed that specimens from South Carolina and Tennessee differed significantly for only 1 character, UPM2M3 (Table 4). Nonparametric comparisons revealed no significant differences among samples from South Carolina, Tennessee, and Virginia (X^2_{15}= 0.1 - 4.5, $P>0.10$).

A stepwise discriminant function analysis was performed using 20 cranial measurements from 41 specimens as predictors of membership in 3 groups (defined in Fig. 5). Although 2 functions were derived, no significant discriminating power remained after removal of the first function ($X^2_9=4.3$, $P=0.90$). The first function accounted for 97.6 percent of the between-group variability. Ten cranial characters in combination were found to be useful in discriminating between groups. MANDLEN (-4.0), DIASTEMA (2.6), UPM2M3 (1.6), and NASALWID (-1.5) were among the most important discriminators on the first function.

Specimens from South Carolina and Tennessee were clearly distinguished on the first function (Fig. 5). Virginia specimens were intermediate, overlapping both the South Carolina and Tennessee polygons to a slight degree. Forty (97.6%) specimens of the O. v. virginianus group were correctly classified as to region of origin. The single misclassification involved a skull from Virginia which was grouped with South Carolina specimens.

Regional Comparisons.-- In order to examine patterns of regional variation within and across subspecies, a stepwise discriminant function analysis was performed using 20 cranial measurements from 175 individuals as predictors of membership in 10 groups (defined in Fig. 6). Nine functions were derived, however, after removal of the first 3 functions, no significant discriminatory power remained ($X^2_{65}=80.4$, $P=0.10$). The first, second, and third functions accounted for 51, 20, and 10 percent of the between-group variability, respectively. Seventeen characters in combination were useful in discriminating between groups. DIASTEMA (-1.0), CONDYLO (0.9), and GREATLEN (-0.8) were important discriminators on the first function; CONDYLO (-1.8), PALATLEN (1.5), POSTPAL (1.2), and INCISIVE (-0.8) were the primary distinguishing variables on the second function.

Samples of O. virginianus from 10 regions of the eastern and midwestern United States exhibited two overlapping distributions, 1 represented by smaller forms from more southern localities, the other by larger forms from higher latitudes (Fig. 6). Specimens from Kansas clustered with the larger specimens. Within these 2 distributions, South Carolina and Minnesota were most differentiated, based on the positioning of group centroids. These 2 groups exhibited very little overlap with samples from the other "type" (large vs. small); 1 Pennsylvania specimen fell on the periphery of the South Carolina polygon, while 1 Virginia specimen fell within the Minnesota polygon. Specimens from Missouri were largely differentiated on the first 2 functions combined, though were intermediate between the large and small morphotypes on the first function.

One-hundred and twenty-three (70.3%) specimens were correctly classified. Sixty-one (86.0%), 31 (79.5%), and 47 (72.3%) specimens representing O. v. borealis, O. v.

virginianus, and O. v. macrourus were correctly classified to subspecies, respectively. Of 52 misclassifications, 10 (19.2%) occurred within the small morphotype (AR-SC-TN-VA) and 25 (48.1%) occurred within the large morphotype (KS-PA-MI-ME-MN). The greatest number of misclassifications between 2 regions involved 6 (24.0%) Kansas specimens grouped with Michigan. Eighteen (78.3%) of Missouri specimens were correctly classified; 2 (8.7%), 2 (8.7%), and 1 (4.4%) specimen(s) were grouped with Pennsylvania, Michigan, and Tennessee, respectively.

Illinois Comparisons

Cranial.-- Univariate comparisons of O. virginianus skulls from Illinois revealed 15 characters with significant levels of geographic variability (Table 5). Deer from southern Illinois averaged smaller than specimens from the westcentral, northwestern, eastcentral, and southcentral portions of the state for 12, 11, 9, and 5 cranial measurements, respectively (Table 5). Specimens from Effingham County, Illinois, were significantly larger for 10 characters, when compared to skulls from the southern region.

Comparisons between more northerly (southern Illinois excepted) regions of the state were less conclusive. The following pairwise comparisons were significant at the $P<0.01$ level; the value in parentheses represents the number of characters for which means differed between regions: westcentral < eastcentral (2), southcentral < eastcentral (3), northwestern < Effingham (2), and southcentral < Effingham (1).

Ten characters exhibited clinal variation for size consistent with Bergmann's Rule, beginning in southern Illinois and progressing northward through westcentral and northwestern Illinois (Table 5). Six characters displayed this trend of increasing size with latitude from southern Illinois northward through southcentral, Effingham County, and eastcentral Illinois. Specimens from eastcentral Illinois, however, averaged larger or equal to those from northwestern Illinois for 15 measurements, and were larger than all Illinois regions for 11 characters. These patterns were apparent for PALATLEN, the most geographically-variable of 20 characters examined (Fig. 7). Correlations between PALATLEN and the remaining 19 characters ($r=0.32 - 0.42$, $\underline{P}<0.001$) suggested similar ds for all craniodental measurements. Broad, overlapping ranges and large standard deviations suggested considerable individual character variation. A character shift or step was apparent, however, for southern Illinois.

Regional patterns of morphological variation within Illinois were examined with a stepwise discriminant function analysis using 20 cranial measurements from a total of 244 specimens as predictors of membership in 6 groups (defined in Fig. 8). Although 5 functions were derived, no significant discriminatory power remained after removal of the first 3 functions (X^2 $=15.7$, $\underline{P}=0.21$). The first, second, and third functions accounted for 51, 23, and 13 percent of the between-group variability, respectively.

Fifteen characters in combination helped distinguish between groups. CONDYLO (1.8) and POSTPAL (-1.0) were the most important discriminating variables on the first function; CONDYLO (-1.8), UPM2M3 (1.6), and LPM2M3 (-1.2) were the primary distinguishing variables on the second function.

In a bivariate plot of the canonical-variates scores, specimens from northwestern, eastcentral, and Effingham County, Illinois overlapped to a considerable degree and group centroids from these regions were closely clustered (Fig. 8). These samples overlapped the southcentral and westcentral polygons to a large degree, though the latter 2 groups were largely differentiated on the second function. The northwestern Illinois polygon enclosed a large proportion of the specimens from eastcentral, westcentral, southcentral, and Effingham County, Illinois.

Although all groups overlapped the southern Illinois polygon to varying degrees, the degree of nonoverlap and positioning of group centroids indicated that the southern Illinois sample was somewhat differentiated in the first function (Fig. 8). One-hundred and fifty-one (61.6%) specimens were correctly classified as to region of origin. Correct classifications ranged from 83.1 (southern) to 47.4 (southcentral) percent. Of 94 misclassifications, 75 (79.8%) were misclassed as northwestern (27), westcentral (27), or southern (21) Illinois specimens.

External.-- Univariate comparisons of 6 body measurements of adult female O. virginianus from 3 regions of Illinois revealed 3 characters which exhibited significant levels of geographic-variability (Table 6). Specimens from southern Illinois averaged significantly smaller than specimens from northwestern and westcentral Illinois for FOOT, TOTAL, and HGTSHLDR (Table 6). FOOT and EAR exhibited clinal variation for size consistent with Bergmann's Rule, beginning in southern Illinois and progressing northward through westcentral and northwestern portions of the state. Regional comparisons of 5 of these measurements expressed as a proportion of total body length indicated that deer from southern Illinois averaged significantly larger for ear length/total length than animals from either northwestern or westcentral Illinois ($F_{2,51} = 7.8$, $P < 0.001$).

A stepwise discriminant function analysis was performed using 6 external measurements from a total of 79 specimens as predictors of membership in 3 groups (defined in Fig. 9). Two functions were derived; after removal of the first function, no significant discriminatory power remained (X^2_3=7.6, P=0.06). The first function accounted for 96.4% of the between-group variability.

Four characters in combination were useful in discriminating groups. FOOT (1.0) was the primary distinguishing variable on the first function. In a bivariate plot of canonical-variates scores the westcentral and northwestern Illinois polygons overlapped to a considerable degree (Fig. 9). The sample from southern Illinois was differentiated on the first function.

Sixty-one (79.2%) specimens were correctly classified to region. On a regional level, 28 (96.6%), 20 (74.1%), and 13 (61.9%) specimens from the southern, westcentral, and northwestern portions of the state were correctly classified to region of origin, respectively. One specimen from southern Illinois was grouped with northwestern Illinois, while 1 specimen from westcentral Illinois was misclassed as southern Illinois. The remaining 14 misclassifications were between the northwestern and westcentral regions of the state.

Subspecific Status of Regional Illinois Deer Herds

Discriminant Function Analysis.-- In order to examine the subspecific status of regional Illinois deer herds relative to specimens representing *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus*, a stepwise discriminant function analysis was performed using 20 cranial measurements from a total of 361 specimens as predictors of membership in 9 groups (Fig. 10); southern Illinois specimens were considered unknowns. Seven functions were derived; after removal of the first 3 functions, no significant discriminating power remained ($X^2_{42}=66.6$, $\underline{P}=0.01$). The first, second, and third functions accounted for 58, 16, and 10 percent of the between-group variability, respectively.

Eighteen characters in combination were useful in distinguishing groups. LPM2M3 (0.7), UPM2M3 (-0.5), and PALATLEN (0.5) were among the most important discriminators on the first function; CONDYLO (-1.9), PALATLEN (1.3), and UPM2M3 (1.1) were the primary distinguishing variables on the second function.

In a bivariate plot of canonical-variates scores samples from northwestern, westcentral, eastcentral, Effingham County, and southcentral Illinois overlapped to a considerable degree and are enclosed within a single polygon (Fig. 10). The sample from southern Illinois was nearly completely enclosed by the combined Illinois polygon. Both the O. v. borealis and O. v. macrourus samples overlapped the Illinois and southern Illinois polygons, as well as each other, to a large degree. The O. v. virginianus sample was somewhat differentiated from O. v. borealis, Illinois, and southern Illinois on the first function, although it overlapped the O. v. macrourus polygon to an appreciable degree.

One-hundred and ninety-five (54.0%) "known" specimens were correctly classified to region (Table 7). Correct classifications ranged from 31.6 to 74.4 percent. A relatively large number of misclassifications occurred between O. v. macrourus and O. v. borealis. Within Illinois, a large number of misclassifications involved the northwestern and westcentral portions of the state.

Twenty (62.0%), 14 (40.0%), and 1 (10.0%) specimen(s) of misclassed O. v. borealis, O. v. macrourus, and O. v. virginianus, respectively, were categorized as Illinois specimens. Sixteen (80.0%) misclassed O. v. borealis were grouped with northwestern of westcentral Illinois (Table 7). Overall, 83% of O. v. borealis were classified as O. v. borealis (including Illinois). Of 45 Illinois specimens misclassed as O. v. borealis, O. v. macrourus, or O. v. virginianus, 30 grouped with borealis; the remainder were classed as O. v. macrourus.

Thirty-two (54.2%) southern Illinois specimens (classed a priori as unknowns) grouped with Illinois skulls, primarily those from northwestern and westcentral Illinois (Table 7). A large proportion were categorized as O. v. borealis or O. v. macrourus; only 1 specimen grouped with O. v. virginianus. A second discriminant function analysis was performed using 19 cranial characters expressed as a proportion of the greatest length of the skull as predictors of membership in 8 groups; southern Illinois specimens were again considered unknowns.

One-hundred and seventy (47.1%) "known" specimens were correctly classified to region (Table 8). Correct classifications ranged from 21.1 to 59.3 percent. For O. v. macrourus, a slight increase in the number of correct classifications was apparent when compared to the raw data. Ninety-four percent of O. v. borealis were classified as O. v. borealis (including Illinois), compared to 83% for the raw data. The sample of O. v. virginianus exhibited a substantial increase in the number of correct classifications. Twenty-five (71.4%), 33 (42.4%), and 4 (20.0%) specimens of misclassed O. v. borealis, O. v. macrourus, and O. v. virginianus, respectively, were categorized as Illinois specimens.

Each of the 5 Illinois regions used in calculating classification functions exhibited a decrease in the number of correct classifications and an increase in the number of specimens misclassed as 1 of 3 subspecies (Table 8). Thirty-three, 21, and 2 Illinois specimens grouped with O. v. borealis, O. v. macrourus, and O. v. virginianus, respectively.

Forty-five (76.3%) southern Illinois specimens (classed a priori as unknowns) grouped with Illinois skulls, primarily westcentral and northwestern regions of the state. A considerably smaller number were misclassed as O. v. macrourus or O. v. borealis, when compared to classifications resulting from the raw data (Table 7); as in the previous analysis, only 1 specimen grouped with O. v. virginianus.

An additional stepwise discriminant function analysis was performed using 20 cranial characters as predictors of membership in 8 groups, including the small (Arkansas, South Carolina, Tennessee, and Virginia), large (Kansas, Maine, Michigan, Minnesota, and Pennsylvania), and Missouri morphotypes; southern Illinois specimens were treated as unknowns. Two-hundred and sixteen (59.8%) "known" specimens were correctly classified (Table 9). Correct classifications ranged from 26.3 to 85.7 percent. While few (5.4%) specimens representing the small morphotype were grouped with Illinois, a relatively large number of skulls representing the large morphotype (28.1%) were classed as Illinois specimens.

Of 99 misclassified Illinois specimens, 53 (53.5%) grouped with the large morphotype, while 41 (46.4%) were ranked with other regions of Illinois (primarily the northwestern, westcentral, and eastcentral regions); none grouped with the small morphotype.

Twenty-nine (49.2%) southern Illinois specimens (classed a priori as unknowns) grouped with Illinois skulls, primarily the northwestern and westcentral portions of the state.

A larger proportion (30.5%) of southern Illinois specimens grouped with the large morphotype, as compared to the small morphotype (11.9%).

Phenetic Clustering.-- A phenogram based upon standardized character means produced two primary groups, 1 including samples representing the small morphotype, the other containing samples representing the large morphotype (Fig. 11). Within the latter group 2 secondary groups were distinguished, 1 comprised of samples from Missouri, Pennsylvania, and southern Illinois, the other consisting of the remaining regions. Samples from Missouri, Pennsylvania, and southern Illinois averaged somewhat intermediate between the 2 morphotypes for most characters.

Principal Components Analysis.-- According to Thorpe (1983) and others, interpreting ordinations using large samples can be misleading, given the large degree of individual variation. Principal components derived from character means may provide a better means of identifying patterns. As recommended by Chernoff (1982) and Matthews (1987), 2 sets of 5 localities were chosen randomly, with the stipulation that no more than 2 localities from the same subspecies, or from within Illinois, be included within the same set, and that N > 5. Each set was then subjected to a sheared principal components analysis to determine if at least some localities could be distinguished in principal component space.

Loadings on the size axis indicated that skeletal characters were of greater importance to the size component than were dental characters (UPM2M3 or LPM2M3). Loadings on the sheared PC-II axis for the first random set of regions contrasts the width of the nasals (NASALWID), and to a lesser degree width of the rostrum (ROSTRAL) with all of the length measurements (particularly length of the nasals, NASALEN) and height of the mandible (MANDHT) (Table 10). Thus, specimens with shorter skulls and "shorter" mandibles have broader nasals and to a lesser degree broader rostra. Loadings on the sheared PC-III axis contrast length of the incisive foramin (INCISIVE) with the width of the rostrum (ROSTRAL), postpalatal length (POSTPAL), and width across the occipital condyles (CONDYLAR). Thus, specimens with longer incisive foramina are characterized by narrower rostra, shorter skulls posterior to the palate, and are narrower across the occipital condyles.

Ordination of individual component scores for the first random set of regions revealed much overlap between groups on the size and sheared PC-II axes (Fig. 12). The Missouri and Tennessee samples were largely separated on the combined sheared PC-II and sheared PC-III axes (Fig. 13). The Tennessee sample was differentiated from the remaining samples, albeit to a lesser degree. The northwestern Illinois, southcentral Illinois and Kansas samples overlapped to a considerable degree.

Loadings on the size axis again indicated that skeletal characters were of greater importance to this axis than were dental characters. Loadings on the sheared PC-II axis for the second random set of regions contrasted the width of the nasals (NASALWID) with all of the length measurements (particularly NASALEN and DIASTEMA) (Table 11). Thus, specimens with shorter skulls are characterized by broader nasals. Loadings on the sheared PC-III axis contrasted the length of the incisive foramin (INCISIVE) and to a lesser degree the length of the diastema (DIASTEMA) with the length of the upper and lower molariform tooth rows (UPM2M3, LPM2M3), length of the skull posterior to the palate (POSTPAL), height of the mandible (MANDHT), and 3 width measurements (M2M2, CONDYLAR, ROSTRAL).

Ordination of individual principal component scores for the second random set of regions revealed much overlap between groups on the size axis (Fig. 14). The Minnesota polygon exhibited moderate separation from the South Carolina sample on the sheared PC-II axis. Southern Illinois showed moderate overlap with South Carolina and Minnesota, and some separation from Michigan and westcentral Illinois. The westcentral Illinois, Minnesota, and Michigan samples overlapped to a large degree. The South Carolina and Minnesota samples were clearly separated on the combined sheared PC-II and sheared PC-III axes (Fig. 15), and to a lesser degree on the sheared PC-III axis alone. The southern Illinois polygon was shifted toward the lower right, though maintained a similar relationship with the other groups as previously described. Given the degree of overlap and lack of clear separation between groups, ordination based on character means could produce random or misleading results (Chernoff 1982; Matthews 1987), thus no further analysis appeared warranted.

Latitudinal Variation

Skeletal.-- Examination of character means by region (Tables 2,3,4,5, and 6) revealed that on a broad geographic scale white-tailed deer do exhibit clinal variation consistent with Bergmann's Rule (e.g. TN < southern IL < westcentral IL < northwestern IL; AR < KS < MN; SC < PA < ME). A closer examination revealed exceptions to this rule. For example, specimens from eastcentral Illinois averaged larger than those from westcentral Illinois and were slightly larger when compared to skulls from northwestern portion of the state. Similarly, both the Maine and Michigan samples averaged somewhat smaller than the northwestern Illinois sample, while the eastcentral Illinois sample was similar in size to the Minnesota sample. Specimens from Missouri averaged larger than those from southern Illinois.

Eviscerated Mass.-- With few exceptions counties occupying the northern two-thirds of Illinois were characterized by "average" (within +/- 1 S.D. of mean) or "above-average" (> 1 S.D. above mean) animals (Figs. 16-21). "Below-average" (< 1 S.D. below mean) deer were primarily restricted to the southern third of the state. Male fawns deviated most from this pattern (Fig. 17).

All age/sex classes were significantly correlated with latitude ($P < 0.0001$)). Correlations between latitude and mean mass of antlered males ($r=0.44 - 0.47$) were conspicuously lower than other classes ($r=0.62 - 0.68$).

The pattern of latitudinal distribution in mean mass (Figs. 16-21) suggested a curvilinear relationship, with above-average deer primarily associated with counties at middle latitudes. Polynomial regression analysis revealed significant nonlinear trends between weight and latitude ($F_{2,73}= 66.9 - 123.3$, $P < 0.001$). Terms beyond the quadratic were not significant. This model accounted for a large portion of the variance in mass by sex/age class ($R^2= 0.65 - 0.77$).

Regression analyses examining relationships between eviscerated mass by age/sex class and latitude, soil fertility, percentage of county in forest, and hunter success revealed that the independent variables accounted for a moderate proportion of the variance in mass

(Table 12). These parameters described a greater proportion of the variance in females, when compared to males of the same age class.

Multiple correlations (R) and multiple correlations squared (R^2) for antlered males were conspicuously lower when compared to male fawns or females of any age. Latitude contributed most to prediction of eviscerated mass in male and female fawns, and yearling females, although hunter success was nearly as important in it's contribution to variability of mass in fawn and yearling females (Table 12). Hunter success was the variable most important in the reduction of residual variation in adult and yearling males, and was equal in magnitude to % county in forest in it's contribution to prediction of mass in adult females.

Residuals resulting from the above regression models were grouped by region (Fig. 22). With the exception of yearling females, mean residuals from central Illinois were significantly larger than those from either northern or southern Illinois (Table 13). Contrasts comparing residuals of yearling females from central Illinois with northern and southern Illinois approached significance. Mean residuals did not differ significantly between northern and southern Illinois. Mean residuals from northern and southern Illinois did not differ from zero (x_{res}= -0.84 - -2.34, t_{78}= -1.1 - -1.87, $\underline{P}>0.05$). However, mean residuals from central Illinois were greater than zero (x_{res}= 1.51 - 4.03, t_{78}= 2.24 - 3.75, $\underline{P}<0.05$).

With the exception of yearling females from northern Illinois, the 4 independent variables accounted for a moderate to large proportion of the variance in mass of deer from southern and northern reaches of the state (Table 14). In each case the model accounted for a greater proportion of the variance in mass of deer from southern versus northern Illinois. These parameters accounted for an insignificant amount of the variance in mass of deer from central Illinois. In those cases where a significant regression was obtained, latitude contributed most to prediction of mean eviscerated mass (Table 14). The contribution of the other parameters varied among age/sex classes and regions, and was greatest for male fawns from northern Illinois, and both adult and fawn females from northern and southern Illinois. The importance of each parameter also varied, with soil fertility and % forest contributing greatly to prediction of mass in fawns (both sexes) and adult females from northern Illinois, while % forest and hunter success were important in their contribution to variance in eviscerated mass in adult and fawn females from southern Illinois.

With the exception of yearling females, mean mass of white-tailed deer cohorts from northern Illinois were negatively correlated with latitude ($r= -0.50$ - -0.70, $\underline{P}<0.05$), while for southern Illinois all age/sex classes were positively correlated with latitude ($r= 0.76$ - 0.83., $\underline{P}<0.001$). For central Illinois, only fawns were correlated with latitude ($r= 0.44$ - 0.45, $\underline{P}<0.05$).

Of the independent variables, only % forest was correlated with latitude in southern Illinois ($r= -0.64$, $\underline{P}<0.001$). Percent forest was strongly negatively correlated with percent cropland ($r= -0.94$, $\underline{P}<0.001$). Only soil fertility was correlated with latitude in central Illinois ($r= 0.52$, $\underline{P}<0.01$), while none of the independent variables was correlated with latitude in northern Illinois.

On a statewide basis, latitude was highly correlated with length of growing season, mean January temperature, and mean annual snowfall ($r= -0.90$, -0.95, and 0.94, respectively, ($\underline{P}<0.0001$). Regional variation in the relationship between latitude and these meteorological parameters was, however, apparent (Table 15).

DISCUSSION

The study of geographic variation is central to biogeography and the study of speciation (hence evolution), and is of great importance to biologists interested in qualitative differences between populations and the reasons behind such differences. There is need, however, for standardization and stricter criteria in defining subspecies, if this category is to remain useful to such research endeavors. Subspecific designations should be based on concordant character trends, breaks or "steps" in character gradients coinciding with at least partial barriers to gene flow or lines of abrupt environmental change, and the degree of differentiation (e.g. 95% rule).

Intergradation between contiguous subspecies and reintroductions with animals of differing stock has made classification of white-tailed deer difficult. Boundaries between purported subspecies were often drawn somewhat arbitrarily, though natural boundaries (e.g. major river courses) were included where possible (Kellogg 1956). Kellogg (1956) and later Baker (1984) suggested that a modern re-evaluation of geographic variation in this species would yield much the same classification.

Populations from disjunct areas within the presumed ranges of the subspecies examined were for the most part morphologically distinguishable when limited numbers of samples and specimens were examined. O. v. borealis samples from Minnesota, Maine, and Pennsylvania were separable, whereas the Michigan sample overlapped the Pennsylvania sample to a slight degree. The Maine and Minnesota polygons coincided with the Michigan sample to a large degree, whereas the Maine sample exhibited a closer relationship with Minnesota than with Pennsylvania. The UPGMA phenogram also indicated a close relationship between Maine and Michigan. This agrees with Rees'(1969b) study of geographic variation in deer mandibles in which Maine specimens grouped with northcentral samples.

Deer inhabiting the regions of Maine, Michigan, and Minnesota that were sampled were descended from the original herds occupying these areas (R. Dressler (ME) pers. commun.; S. Schmitt (MI) pers. commun.; J. Mooty (MN) pers. commun.). Although the Commonwealth of Pennsylvania purchased and released deer from a number of states (primarily Michigan), no record of release sites exists (W. Shope pers. Commun.). Laws protecting remnant herds and relocations within the state allowed the native herd to recover rapidly. Thus, introduced genes may have been swamped or lost through competition with native populations.

Samples of O. v. macrourus from Arkansas, Kansas, and Missouri were clearly distinguishable using univariate and multivariate techniques. The existing Kansas deer herd is the result of expansions of remnant populations following near-extirpation during the late 19th and early 20th centuries (K. Sexson pers. comm.). Similarly, deer from Arkansas are descended from native stock (T. Nelson pers. comm.). The current Missouri herd is a result of the expansion of several remnant populations and restockings of unoccupied ranges using animals from these expanding populations, as well as deer from Michigan and Minnesota (Robb 1959).

Univariate comparisons were of little value in distinguishing O. v. virginianus from South Carolina, Tennessee, and Virginia, however, these populations were separable in multivariate space. The existing Savannah River Plant herd is descended from remnants of native herds which persisted along the Savannah River corridor (Hillestad 1984). The restoration of the Tennessee herd has a complex history, though it seems deer from the southwestern portion of the state are descended from animals relocated from Ft. Campbell and Chuck Swan WMA, both in Tennessee (Tenn. Wildl. Res. Agency 1991). The Ft. Campbell herd resulted from reintroductions with deer from Oklahoma and Texas, while the Chuck Swan herd was descended from North Carolina stock. The small size of the Virginia sample precluded meaningful analysis.

The use of a larger number of groups and specimens resulted in an inability to distinguish between some groups which were clearly separable in previous analyses (e.g. SC, TN, & VA; ME, MN, and PA). Discriminant function, canonical variates, and UPGMA cluster analyses revealed that deer were assignable to 2 major groups, one containing large deer from within the accepted range of _O_. _v_. _borealis_ as well as northeastern Kansas and southeastern Missouri, the other comprised of smaller deer from within the range of _O_. _v_. _virginianus_ and including Arkansas. These groups may be allocated to _O_. _v_. _borealis_ and _O_. _v_. _virginianus_, respectively, given further study of character gradients across subspecies boundaries, particularly those which might restrict gene flow (e.g. Ohio and Potomac rivers).

Although some researchers have found a degree of genetic and/or morphologic divergence between geographically distant or isolated (e.g. island) forms (McCain 1970; Brisbin and Lenarz 1984; Hillestad 1984; Smith et al. 1986; Gavin and May 1988; Maffei et al. 1988; Ellsworth 1991), electrophoretic studies have revealed little basis for subspecific differentiation in parapatric subspecies (Hillestad 1984; Smith et al. 1984, Gavin and May 1988). This lack of divergence between subspecies may be an artifact of the limitations of protein electrophresis. Lack of sufficient allozymic variability and the relatively low resolving power of this technique may make other molecular methods more appropriate (Murphy et al. 1990). Only about 30% of nucleotide substitutions may be detectable using gel electrophoresis (Shaw 1970). Thus, considerable genetic variation may go undetected. The limited number of loci resolved (Murphy et al. 1970), biased sampling of loci (Avise 1975), and the possibility that morphometric and other functional attributes are controlled by a small number of regulator loci (Wilson et al. 1977) heighten the possibility that loci encoding for phenotypic characters important in intraspecific divergence have not been examined.

Ellsworth et al. (1990), using restriction endonuclease analysis of mtDNA, identified 3 distinct haplotype assemblages of white-tailed deer in the southeastern United States; these assemblages were not congruent with current subspecific classification of this species. Further analysis of interspecific variation using such molecular techniques may identify patterns corresponding with those based upon phenotypic characteristics. However, Calhoun et al. (1988) suggested that phenotypic differentiation may occur in response to external adaptive pressures, while the internal environment may resist genetic differentiation. Under such conditions, classical systematic data may offer a greater degree of resolution.

The northeastern Kansas sample clustered with the large morphotype, and exhibited a closer relationship with 5 Illinois regions (southern excepted) than with Arkansas and Missouri. Rees (1969b) found that mandibles from both northeastern and southeastern Kansas grouped with northcentral samples. It is tempting to speculate that the relationship between the Missouri sample and the large and small morphotypes is the result of introgression between native deer and northern stock used in reintroductions. Indeed, Minnesota x Missouri hybrids were used to stock some areas (Robb 1959). Rees (1969b) found that archeological and contemporary Missouri samples grouped with the northcentral region, based on a series of dental characters. The archeological sample was, however, of unknown sex ratio. It is possible that these animals represent phenotypic intergradation between the northern and southern forms.

The UPGMA cluster analysis indicated that Missouri, Pennsylvania, and southern Illinois formed a secondary cluster within that cluster comprised of the large morphotypes. The southern Illinois and southeastern Missouri sampling localities were geographically close. The Illinois and Missouri herds are separated by the Mississippi River, which provides a partial barrier to gene flow. While it is likely that some genetic interchange is occurring, these herds are also constrained by similar environmental conditions. This argument (parapatry) does not explain the relationship between deer from southern Illinois and southeastern Missouri and the Pennsylvania sample. Deer from these regions may to some extent share a common genetic background, since deer from Michigan were used in restocking programs in Illinois, Missouri, and Pennsylvania (Robb 1959; Pietsch 1954; W. Shope pers. commun.). The degree to which these introduced genes were swamped or lost through competition with better-adapted native stock remains unknown. Rees (1969b) found that while both contemporary and archeological samples from Missouri grouped with the northcentral samples, an archeological sample from Pennsylvania (of unknown sex ratio) incorrectly grouped with the southern sample. This Pennsylvania sample was collected from a site located several hundred miles distant and in a different physiographic province than the current sample.

Based on phenetic clustering and canonical variates analyses deer from Illinois grouped with the large morphotype. The southern Illinois samples averaged smaller than the other regions of Illinois for a number of cranial and external measurements. Few differences between the other regions of Illinois were apparent.

Considerable overlap and misclassification between 5 regions of Illinois was apparent. The southern Illinois sample was somewhat differentiated based upon positioning of group centroids and degree of nonoverlap, and had the highest rate of correct classification (83%). Comparisons of external characters revealed that southern Illinois was nearly distinct, while the northwestern and westcentral regions exhibited near-total overlap.

Considerable overlap between O. v. borealis and Illinois (including southern) samples was apparent. This agrees with the original classification of O. v. borealis, which included all of Illinois (Hall 1981). The O. v. virginianus sample was largely differentiated from O. v. borealis (including Illinois). Few misclassifications occurred between O. v. borealis and O. v. virginianus. Of the Illinois samples, 1 specimen (from southern Illinois) was misclassed as O. v. virginianus. These results suggest that O. v. borealis and O. v. virginianus are morphologically distinct forms, and that deer from Illinois (including southern Illinois) are assignable to O. v. borealis.

The degree of overlap between O. v. macrourus and O. v. borealis was primarily due to the misclassification of a relatively large number of O. v. macrourus specimens as O. v.

borealis or Illinois. A moderate number of southern Illinois specimens were misclassed as *O. v. macrourus*.

The considerable overlap between the *O. v. macrourus* and *O. v. virginianus* samples was presumably due to the small size of the Arkansas specimens. In fact, all 9 *O. v. macrourus* skulls misclassed as *O. v. virginianus* were Arkansas specimens. This finding suggests that *O. v. macrourus* is a synonym of *O. v. borealis*, and that smaller deer from more southerly reaches of this range may be allocated to *O. v. virginianus*. The presence of the Mississippi River restricting east-west genetic interchange, and the apparent lack of any such barriers between Missouri and Arkansas is problematic. According to Endler's (1972) ecotone model, abrupt environmental changes need not be large to produce steep clines in character gradients. The degree of geographic differentiation would be increased by stronger selection pressures and decreased by stronger gene flow. Thus, deer could be subject to strongly divergent selection pressures in the face of apparent gene flow (e.g. across the oak-hickory - southern coastal plain ecotone in northcentral Arkansas). Similarly, deer from the northcentral (southcentral) and northeastern (southeastern) United States may be undergoing "selection by common environmental factors" (Gould and Johnston 1972:466) and thus little differentiation in light of partial barriers to gene flow (e.g. Mississippi River). Further investigation into the relationship between these groups, as well as between *O. v. macrourus* and *O. v. dacotensis* to the northwest, *O. v. texanus* to the southwest, and *O. v. mcilhennyi* to the south is warranted.

The use of ratios to distinguish between taxa produced mixed results, increasing the correct classification of some forms, while decreasing it in other. Ratios increased the number of southern Illinois specimens classed as O. v. borealis (including Illinois), decreased the number misclassed as O. v. macrourus, and had no effect on the number grouped with O. v. virginianus.

McCain (1970) and Maffei et al. (1988) proposed that cranial ratios may be useful in distinguishing between Key deer (O. v. clavium) and larger forms. The former indicated that such ratios were useful if significant differences occurred in the original measurements comprising the ratios, suggesting that these indices may contribute little, if any, to discrimination of races or populations beyond that of the original characters. Results of the present study demonstrated that the use of ratios to identify groups may produce conflicting results with regard to raw data and/or current taxonomy. Atchley et al. (1976) and Atchley and Anderson (1978) reached similar conclusions regarding the use of ratios in systematic studies.

The relationship between environmental and genetic components of phenotype in white-tailed deer is not well-understood. Although demographic, mass, skeletal, and antler characteristics reflect nutritional plane (and so range conditions) (Johnson 1937; Cheatum and Severinghaus 1950; Brohn and Robb 1955; Severinghaus and Cheatum 1956; Klein 1964; Severinghaus and Moen 1983; Ullery 1983), these traits are also under genetic control (Ramsey et al. 1979; Harmel 1983; Smith et al. 1983). Ramsey et al. (1979) and Brisbin and Lenarz (1984) found concomitant demographic, morphometric, and genetic differences between deer from adjacent upland and lowland habitats. Rees (1970) theorized that dissimilarities in skull shape between deer from Upper and Lower Michigan (separated by the Strait of Macinac) reflected genetic isolation of the 2 groups, while better range conditions were responsible for the larger size of crania from southern Lower Michigan when compared to deer from northern Lower Michigan. Atchley et al.(1981) identified certain skull characters in Mus musculus which were correlated with the genetic component of phenotype, others which correlated with the environmental component, and others on which genetics and environment had equal influence.

Character loadings on the first principal component for both random sets of localities indicated that the size component was a function of skeletal rather than dental size. This contradicts the findings of Rees (1969b), who indicated that size variation in the mandible was more a function of dental than skeletal size.

Results indicated a wide range of variation in skull characteristics, thus a large degree of within-group variation. Sheared principal components analysis of random groups indicated a relatively large size component to this variation. Some of this variation is undoubtedly ecophenotypic in nature (e.g. nutritional plane), and may also partly reflect a large degree of individual variation, which would be expected in a large, herbivorous placental occupying a broad niche (Long 1969). The white-tailed deer exhibits a high degree of genetic and morphometric variation at the individual level (Long 1968; Smith et al. 1984). Body size, however, is characterized by moderate to high levels of heritability (Atchley 1983). Size is a polygenically-controlled trait, and as such is an important component involved in genetic (or evolutionary) tracking of the environment (Bryant 1977). Thus, some unidentified portion of this wide range of variation in size likely represents adaptive responses to local or regional conditions. This variation could be maintained in the presence of relatively weak selection pressures, given the low rate of interdemic gene flow in this species.

Loadings on the sheared PC-II and sheared PC-III axes suggested a length-width relationship, in that animals with longer skulls have narrower crania (particularly rostra or nasals), and, conversely, those with shorter skulls have broader crania. McCain (1970) found a change in the proportion of skull length and width with age in O. v. clavium, in that adults had a proportionally wider skull. Both McCain (1970) and Maffei et al. (1988) suggested several length-width ratios which they felt might be useful in distinguishing some subspecies. Loadings on the major shape axis (sheared PC-II) indicated the importance of nasal width and to a lesser degree mandible height to this component. In a study of the genetic and environmental components of size and shape in the house mouse (Mus musculus), Atchley et al. (1981) found these 2 characters to be correlated with the genetic component.

Humphries et al. (1981:291) defined shape as the "geometry of the organism after information about position, scale, and orientation has been removed". It has been suggested that variations in the external environment have a greater influence on size than shape (Jolicouer and Mosiman 1960; Rees 1969a, 1970). Thus shape would be a better predictor of genetic affinities between groups. Rees (1969a) felt that genetic affinities among groups might be a function of geographic distance if the following conditions could be met:

> 1) long occupation of the range represented by the breeding groups under consideration,
>
> 2) no behavioral patterns that preclude random mating among neighboring animals,
>
> 3) no migration of animals,
>
> 4) gradual environmental change throughout the range under consideration so that the effect of selection would be a regular function of distance, and,

5) genetic continuum throughout the range represented by the breeding groups under consideration.

Rees (1969a:96) stated that "under these conditions the geographically close groups would have greater genetic affinities than would the more distant groups, so geographic distance could be used to predict relative genetic affinities". Analysis of shape contrasts in the present study suggested greatest separation of those groups with more divergent genetic background, based upon the geographic distance between some groups and the history of relocations of others.

Principal components analyses of 2 random sets of localities revealed considerable within-group variation and, consequently, considerable overlap between most groups. Groups exhibited considerable overlap on the size axis, though some were differentiated to varying degrees on the sheared PC-II and sheared PC-III axes. In the first random sample Tennessee, the only southern group, was differentiated from the other groups. Tennessee showed greater separation from Missouri, its nearest geographic neighbor, than from the other groups. This separation may reflect the genetic ancestry of the latter 2 groups, the southwestern Tennessee herd being descended from North Carolina, Oklahoma, and Texas stock (TN Wildl. Res. Agency 1991), and the Missouri herd being descended from Michigan and Minnesota, as well as native, stock (Robb 1959). Rees (1969b) found that mandible size had not decreased in a Tennessee population descended from northern (MI and WI) stock. However, dispersal and reintroductions, relocations, etc. were not enough to obscure historical patterns of mtDNA differentiation in white-tailed deer from the southeastern United States (Ellsworth 1991).

For the second set of localities, the 2 most geographically-removed regions (MN and SC) exhibited nearly complete separation on the shape axes. Southern Illinois coincided with a slightly greater proportion of the South Carolina sample as compared to Minnesota. Conversely, the westcentral Illinois sample coincided with a considerably greater proportion of the Minnesota sample as compared to South Carolina. Deer from westcentral Illinois may be more closely related genetically to northern deer. Remnant populations probably persisted in more inaccessible portions of southern Illinois (Pietsch 1954; Calhoun and Loomis 1974), thus introduced genes may have been lost through introgression or competition with native stock.

In general, white-tailed deer in this study conform to Bergmann's Rule, although exceptions occurred. According to Bergmann's Rule, homeotherms at higher latitudes should be larger than their counterparts at lower latitudes. The surface-to-volume law is most often evoked to explain this phenomenon. Larger animals have a smaller surface-to-volume ratio and should therefore be more efficient at conserving heat.

Longer ears relative to total body length in deer from southern Illinois agrees with Allen's Rule, which states that homeotherms occupying colder climates have smaller extremities to minimize heat loss, while those living in warmer climes have larger extremities to facilitate cooling. Southern Illinois is characterized by long, hot summers and relatively mild winters, when compared to the central and northern reaches of the state.

Significant correlations between latitude and eviscerated weight of deer by sex/age class also suggested that deer in Illinois exhibit clinal variation in size consistent with Bergmann's Rule. Correlations between latitude and mean mass of antlered males were lower than that of the other classes. Similarly, multiple correlations between mass and latitude, soil fertility, % forest, and hunter success and the proportion of variance in mass accounted for by these variables were lower for antlered males.

On a statewide basis, latitude and hunter success contributed most to prediction of eviscerated mass. Hunter success was positively correlated with mass. This parameter was used as an index of deer density. If higher hunter success reflects higher densities, a negative relationship between mass and hunter success might be expected. However, if high-kill counties represent optimal deer range and populations have not reached carrying capacity, a positive relationship between mass and hunter success might be expected. The ever-increasing success rate enjoyed by Illinois hunters and the above results support this hypothesis. On a statewide basis, latitude was highly correlated with length of growing season, mean January temperature, and mean January snowfall ($r= -0.90$, -0.95, and $+0.94$, respectively), suggesting that mass is at least partly related to latitudinal variation in climatic variability.

Geist (1987) found that most of the terrestrial mammals he examined were smaller above 65°N latitude, suggesting a curvilinear relationship between latitude and body size in homeotherms. He suggested that body size was related to duration of the productivity pulse, and believed that the reason certain mammal species (e.g. white-tailed deer) complied with Bergmann's Rule was that they did not extend above 62°N latitude.

A curvilinear relationship existed between mass and latitude in Illinois (Figs. 16-21). Nonlinear (quadratic) trends explained a large proportion of the variance in eviscerated mass. Such results suggest that the northernmost counties may not provide conditions suitable for maximal mass in deer within the state. Characteristics of counties at middle latitudes may make these areas conducive to greater mass gain.

Regional patterns of variation existed between mass and latitude, soil fertility, % forest, and hunter success. These parameters contributed most to reduction of residual variation in eviscerated mass of deer from southern Illinois. With the exception of yearling females from northern Illinois, these same variables accounted for moderate and insignificant proportions of the total variation in mass in deer from northern and central Illinois, respectively.

Of the independent variables, latitude contributed most to variation in eviscerated mass on a regional level when a significant regression was realized. Deer from northern (yearling females excepted) and southern Illinois were negatively and positively correlated with latitude, respectively, suggesting that larger deer were harvested closer to the central portion of the state. For central Illinois, fawns (male and female) were positively correlated with latitude.

The contribution of the remaining variables to prediction of mass varied between age/sex classes, indicating that these demographic groups may respond differently to the environmental pressures impinging upon them.

The relationship between adult does and fawns (both sexes) and soil fertility, percent forest, and density (hunter success) suggested regional variation in nutritional plane and it's effect on the dam and consequently fetal, neonatal, and fawn growth. Deer from southern and to a lesser degree northern Illinois may find it harder to meet the nutritional demands of pregnancy, lactation, and early growth, when compared to central Illinois.

Extreme southern Illinois is part of the Shawnee Hills physiographic division, which is included in the larger midwest oak-hickory forest region. This area is characterized by a greater proportion of forested uplands, proportionately smaller acreage under cultivation, and poorer soils, when compared to the agricultural lands of central and northern Illinois (Ritchie 1970; Gladfelter 1984; Torgerson and Porath 1984). Torgerson and Porath (1984) suggested that deer in the oak-hickory forest region may have a greater difficulty in meeting nutritional demands. The relationship between mass and latitude (+), mass and percent forest (-), and latitude and percent forest (-) support such claims.

Land-use differences between the northern and central regions of the state are more subtle. In the midwest agricultural region, crops provide a nutritious and abundant food supply (Gladfelter 1984; Nixon et al. 1991). The key to hypothesized nutritional differences between these regions may lie in the availability of such food sources during mid-winter, a critical period in determining fetal (and subsequent fawn) growth and effects on maternal health (Verme and Ullrey 1984). Nixon et al. (1991) indicated that crops and crop residues were generally available throughout the relatively snow-free winters of eastcentral Illinois. The relationship between latitude, mass, and snowfall in northern Illinois suggests that crops may become less available in northern Illinois, and that this, coupled with colder temperatures and a shorter growing season, may result in lighter deer, when compared to central Illinois.

Levins (1965) theorized that genetic heterozygosity in fitness should be related to environmental variation. In response Bryant (1974:11) stated that this "permits an allele to predominate in a species and at the same time allows for considerable variation around this optimum within local populations". Research has indicated high levels of heterozygosity in white-tailed deer, an adaptable and widespread species (Smith et al. 1984). Heterozygosity in this species has indeed been linked to body size (Cothran et al. 1983; Smith et al. 1983), in addition to other functional characteristics.

Patterns of morphological variation in this study indicated that there may be an optimal size for northern deer exposed to one set of conditions (e.g. colder temperatures and shorter growing season), and a different optimal size for southern deer exposed to a different set of conditions (warmer temperatures and longer growing season). Thus these animals are responding to widespread, generalized selection pressures and on a broad geographic scale do conform to Bergmann's Rule. Within this framework adaptive shifts in size (about these optima) may occur in response to local or regional variation in environmental parameters. Consequently, regional exceptions to Bergmann's Rule occur.

MANAGEMENT IMPLICATIONS

Mayr and Ashlock (1991:43) defined the subspecies as "an aggregate of phenotypically similar populations of a species inhabiting a geographic subdivision of the range of that species and differing taxonomically from other populations of that species". Smith and White (1956:188) suggested that taxonomic subspecies should be "based upon genetic differences which produce a phenotypically recognizable difference", thus subspecies would be "functions of their environment and genetic composition". Thus, while acknowledging the need for stricter standards for naming subspecies, the populations forming subspecies may collectively possess phenotypic differences (as compared to other subspecies) of interest to wildlife biologists and managers. Subspecies are protected under the Endangered Species Act of 1973, recognizing that they may have unique needs and perhaps their own evolutionary fate.

The forms identified in this study (*O. v. borealis* and *O. v. virginianus*) may have additional structural as well as physiological and/or genetic characteristics by which they may be differentiated. Further research should examine the relationship between these purported subspecies using an array of characters in an attempt to identify congruent patterns.

Some of the populations examined may have retained characteristics of stock reintroduced into the areas sampled. The degree to which these characteristics were conserved may be dependent upon the number of animals representing native stock inhabiting these areas. Therefore, there may be certain ramifications associated with the relocation of animals in order to incorporate desired characteristics (and, inadvertently, undesirable ones) into existing herds. These observations are based upon circumstantial evidence, although such results suggest interesting possibilities for tracing geneologies using techniques such as mtDNA sequencing.

Game management in Germany has long been conducted on small management units or reviers (Webb 1960). This allows the manager to obtain detailed information on the characteristics of the populations in his/her charge; this information can then be used to formulate a management plan best suited to that particular revier. In the United States, many state agencies have identified deer management units based upon habitat or physiographical characteristics. Other agencies have clung to more traditional management units based on political boundaries.

Biochemical studies have shown white-tailed deer populations to be genetically subdivided across short distances (Manlove et al 1976; Ramsey et al. 1979; Maffei 1985; Sheffield et al. 1985). This information may be useful in identifying functional management units (Smith et al. 1976; Smith et al. 1984), although managing at such a level (local) may not be feasible in most situations. Additionally, it is unclear to what degree genetics contributes to the observed phenotypic variation in this species.

The regional divisions of Illinois identified in this study could form the basis of management units based upon functional characteristics influenced by interactions between land-use, relative density, forage quality (soil fertility), and climatic regime. Fine-tuning of management decisions could be made at the next lower level(s) (i.e., county, physiographic province).

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Table 1. Collection localities, date of collection (except museum specimens) and sample sizes of white-tailed deer skulls examined in this study. Numbers in parentheses indicate portion of that sample represented by borrowed museum specimens.

			Sample Size			
Region	1986	1987	1988	1989	1990	Total
Arkansas	--	8	11	--	--	19
Kansas	--	--	29(5)	--	--	29(5)
Maine	--	--	17	--	--	17
Michigan	--	--	--	24	6(6)	30(6)
Minnesota	24	10	--	--	--	34
Missouri	--	--	27	--	--	27
Pennsylvania	10	7	9(9)	--	--	26(9)
South Carolina	--	--	17	--	--	17
Tennessee	--	--	--	--	23(23)	23
Virginia	--	--	--	--	5(5)	5(5)
northwestern IL	37	--	25	--	--	62
westcentral IL	--	64	7	--	--	71
eastcentral IL	--	--	15	11	--	26
Effingham County	--	--	--	4	16	20
southcentral IL	--	--	--	20	--	20
southern IL	27	47(3)	--	--	--	74(3)
Totals	98	136(3)	157(14)	59	50(34)	500(51)

Table 2. Univariate comparisons of adult female _Odocoileus_ _virginianus_ _borealis_ skulls. Data are mean, S.D., minimum, and maximum in millimeters. Like superscripts denote means not different by Tukey/Kramer multiple comparisons test ($\underline{P}<0.01$).

Character	Pennsylvania (N=26)	Michigan (N=30)	Maine (N=17)	Minnesota (N=24)	F-value^{a}
GREATLEN	273.4A 8.9 260.0-290.0	275.7A 8.0 258.0-294.0	277.9A 10.2 261.0-304.0	284.8A 9.4 269.0-301.0	4.5
CONDYLO	263.0A 7.0 253.0-277.0	267.3A,B 7.2 253.0-281.0	267.8A,B 9.6 252.0-289.0	275.5B 9.3 258.0-294.0	6.1*
NASALEN	89.8A 5.8 79.5-102.8	91.3A 6.1 76.6-101.1	93.0A 3.6 85.7-100.7	94.5A 5.9 84.1-112.3	3.2
NASALWID	16.7A 1.5 13.8-19.9	16.9A 2.2 10.8-20.8	18.6A 1.7 15.9-22.0	17.4A 2.3 13.5-21.6	3.5
INTER	58.8 2.5 53.0-63.6	61.4A 3.3 56.0-68.8	62.6A 3.4 57.2-69.9	61.8A 3.2 55.3-66.9	6.6**
ZYGOMA	106.2A 3.6 97.0-112.0	109.3A,B 4.0 102.0-118.0	109.5A,B 4.7 102.0-119.0	110.4B 3.3 102.0-116.0	5.5*
PALATLEN	174.4A 6.0 162.0-184.0	176.8A 6.3 163.0-189.0	176.9A 7.2 163.0-196.0	180.1A 6.2 173.0-192.0	1.9
PALATWID	26.9A 1.3 24.7-29.7	26.9A 1.3 24.3-29.6	26.8A 1.6 23.5-29.6	27.5A 2.1 24.7-31.9	0.8
UPM2M3	75.4A 3.2 67.6-81.4	76.6A 3.4 71.0-83.0	76.0A 3.9 69.8-81.0	78.3A 3.2 73.9-84.1	2.9
LPM2M3	84.4A,B 3.2 79.9-91.8	83.1A,B 3.7 75.8-91.3	81.7A 4.0 75.8-89.8	86.0B 3.8 79.6-93.9	5.2*
M2M2	73.2A 2.7 67.6-79.3	73.3A 2.8 68.4-79.6	73.3A 2.8 69.2-78.3	76.4 2.1 72.5-79.9	7.9**

Table 2. Continued.

Character	Pennsylvania (N=26)	Michigan (N=30)	Maine (N=17)	Minnesota (N=24)	F-value[a]
DIASTEMA	68.4A 4.1 60.9-74.0	70.7A 3.7 63.3-76.5	71.2A 5.2 62.3-83.7	72.3A 5.2 61.9-81.0	3.1
CRANBD	72.8A 3.0 67.9-77.8	73.7A 1.7 70.3-77.7	73.1A 2.6 69.2-77.8	75.0A 2.3 70.5-77.9	3.6
CRANHT	66.0A 2.6 60.8-71.1	68.2B 2.4 64.5-74.7	67.7A,B 2.1 63.4-71.6	68.9B 2.0 64.1-72.1	7.0**
INCISIVE	37.5A 2.2 33.1-41.0	38.2A 3.0 31.1-46.3	39.9A 3.9 34.3-48.5	38.2A 2.7 33.3-43.3	2.1
POSTPAL	73.3A 3.9 63.7-79.7	73.5A 3.0 66.5-80.6	74.3A 3.8 68.0-80.6	77.0A 4.6 67.2-87.7	4.4
CONDYLAR	48.6A 2.2 44.6-53.4	49.1A 2.2 44.7-53.6	48.2A 1.8 45.6-51.5	51.2 1.7 48.0-55.5	9.0**
ROSTRAL	38.1A 2.1 33.3-42.0	38.6A 3.1 32.6-49.2	39.2A 2.4 35.1-43.2	40.5A 2.6 36.7-44.4	3.5
MANDLEN	213.3A 6.3 203.0-226.0	216.9A 6.7 204.0-231.0	217.8A 8.5 204.0-240.0	221.0A 8.2 205.0-236.0	4.1
MANDHT	101.9A 3.6 95.0-108.0	105.3A 4.7 95.0-113.0	101.4A 6.2 85.0-110.0	109.6 4.3 102.0-117.0	14.6**

$^{*}P<0.01$, $^{**}P<0.001$

[a] 3,73-93 df

Table 3. Univariate comparisons of adult female *Odocoileus virginianus macrourus* skulls. Data are mean, S.D., minimum, and maximum in millimeters. Like superscripts denote means not different by Tukey/Kramer multiple comparison test ($\underline{P}<0.01$).

Character	**Arkansas** (N=18-19)	Missouri (N=24-27)	Kansas (N=26-29)	F-value^{a}
GREATLEN	263.2A 10.8 249.0-288.0	272.6A,B 7.8 255.0-286.0	278.1A,B 12.4 240.0-302.0	10.7**
CONDYLO	252.9 9.8 238.0-273.0	263.0A 7.4 246.0-278.0	269.0A 10.5 236.0-288.0	16.1**
NASALEN	88.9A 6.0 78.5-101.5	91.6A 6.1 81.1-105.2	94.6A 6.4 74.4-106.8	5.1
NASALWID	15.1A 1.4 13.1-18.2	15.9A 1.3 13.2-18.4	17.4 2.2 12.7-22.7	10.9**
INTER	56.8A 2.7 51.8-61.7	59.1A 3.4 51.9-67.5	62.0 3.1 55.5-66.7	16.7**
ZYGOMA	101.8A 3.7 96.0-110.0	105.0A 4.1 98.0-115.0	108.3 3.9 99.0-115.0	16.0**
PALATLEN	165.2 8.4 153.0-183.0	172.8A 6.8 158.0-189.0	177.9A 8.1 157.0-192.0	14.4**
PALATWID	25.2A 1.5 23.0-28.2	26.4A 2.0 23.5-30.8	26.4A 1.4 24.1-29.6	3.8
UPM2M3	73.9A 3.4 68.3-81.5	74.9A 2.9 69.3-81.1	80.9 4.8 72.3-91.5	24.9**
LPM2M3	80.3A 3.5 74.6-85.9	80.4A 3.8 71.1-86.9	86.1 4.2 76.9-96.7	19.2**
M2M2	68.7A 2.4 64.7-72.9	71.6B 2.6 66.7-75.9	73.8C 2.9 66.8-79.1	20.4**

Table 3. Continued.

Character	Arkansas (N=18-19)	Missouri (N=24-27)	Kansas (N=26-29)	F-value[a]
DIASTEMA	68.3A 3.9 60.5-74.1	70.5A 4.0 62.7-77.3	69.5A 5.5 51.6-76.5	1.2
CRANBD	70.0A 2.7 65.4-76.8	71.1A,B 2.9 64.6-77.4	73.3B 3.2 64.6-78.3	7.6[*]
CRANHT	64.0A 1.9 61.1-68.2	65.3A,B 2.8 60.1-70.3	66.7B 2.4 60.5-71.2	6.9[*]
INCISIVE	36.2A,B 2.5 31.2-41.7	34.0A 1.6 30.9-38.2	38.3B 3.0 29.9-42.9	20.3[**]
POSTPAL	71.3 3.2 67.6-80.1	75.6A 2.7 71.0-81.5	74.6A 4.0 66.5-80.0	9.1[**]
CONDYLAR	46.3A 2.2 42.3-48.8	47.6A,B 2.3 43.1-52.0	49.5B 2.6 43.9-55.3	10.3[**]
ROSTRAL	35.4A 2.5 31.6-41.7	36.3A 2.9 29.9-40.9	38.5 2.5 33.4-43.7	9.2[**]
MANDLEN	203.9 7.5 191.0-223.0	212.1A 6.5 200.0-224.0	217.8A 9.2 192.0-240.0	17.8[**]
MANDHT	93.7A 5.7 86.0-110.0	100.8B 5.9 87.0-110.0	107.4C 5.9 94.0-120.0	32.1[**]

[*] *P*<0.01, [**] *P*<0.001

[a] 2,65-72 df

Table 4. Univariate comparisons of adult female *Odocoileus virginianus virginianus* skulls. Data are mean, S.D., minimum, and maximum in millimeters.

Character	Tennessee (N=22-23)	South Carolina (N=16-17)	$t_{1,37}$
GREATLEN	261.6 10.5 242.0-286.0	263.4 6.1 255.0-280.0	0.7
CONDYLO	251.3 9.6 234.0-275.0	252.1 7.8 238.0-270.0	0.3
NASALEN	86.5 5.8 77.5-102.3	88.7 7.0 77.5-107.0	1.1
NASALWID	16.5 1.6 13.5-19.2	15.6 1.2 13.0-17.6	-1.9
INTER	57.7 3.3 52.1-63.3	58.7 2.8 53.8-63.1	1.0
ZYGOMA	102.9 4.4 92.0-111.0	101.9 3.4 97.0-110.0	-0.7
PALATLEN	165.5 8.6 151.0-185.0	166.9 6.2 156.0-184.0	0.6
PALATWID	25.1 1.1 23.6-27.7	25.2 1.7 22.0-27.7	0.2
UPM2M3	71.8 2.7 67.2-76.6	75.4 2.8 70.5-80.5	4.1^{**}
LPM2M3	78.2 2.8 74.4-83.4	79.5 3.0 73.7-85.2	1.3
M2M2	68.3 2.8 60.6-72.7	68.9 2.3 64.9-73.3	0.7
DIASTEMA	66.8 5.4 56.5-77.2	69.6 3.5 63.0-76.4	1.9
CRANBD	70.3 2.7 65.9-75.0	70.2 1.2 67.7-72.3	-0.2
CRANHT	63.3 2.3 59.1-66.8	63.5 2.0 60.9-67.3	0.3
INCISIVE	36.2 2.3 33.0-41.7	37.3 2.1 32.9-40.9	1.5
POSTPAL	69.5 3.6 64.4-77.8	68.9 3.5 61.7-74.3	-0.5
CONDYLAR	45.5 2.2 40.7-49.5	44.5 2.7 38.7-49.6	-1.3
ROSTRAL	35.3 2.1 30.5-38.5	35.5 2.5 32.2-41.0	0.4

Table 4. Continued.

Character	Tennessee (N=22-23)	South Carolina (N=16-17)	$t_{1,37}$
MANDLEN	203.3 8.1 190.0-219.0	203.4 6.5 189.0-217.0	0.1
MANDHT	94.4 5.5 81.0-102.0	93.6 3.7 87.0-101.0	-0.6

[**] $\underline{P}<0.001$

Table 5. Univariate comparisons of adult female *Odocoileus virginianus* skulls from Illinois. Data are mean, S.D., minimum, and maximum in millimeters. Like superscripts denote means not different by Tukey/Kramer multiple comparisons test (*P*<0.01).

Character	Northwestern Illinois (N=62)	Westcentral Illinois (N=71)	Eastcentral Illinois (N=26)	Effingham Co. Illinois (N=19)	Southcentral Illinois (N=20)	Southern Illinois (N=74)	F-value*
GREATLEN	283.1A,b 8.5 267.0-312.0	279.2A 7.8 258.0-295.0	287.8B 10.3 266.0-305.0	281.2A,B 11.7 258.0-297.0	278.0A 8.9 259.0-294.0	268.3 9.3 248.0-291.0	27.1**
CONDYLO	273.1A,B 7.6 259.0-295.0	270.2A,B 8.4 252.0-290.0	276.8A 9.3 259.0-292.0	272.7A,B 10.7 254.0-286.0	267.8B 9.1 250.0-285.0	259.0 9.3 242.0-281.0	26.1**
NASALEN	97.2A 5.7 84.5-111.6	93.8A 5.5 79.0-108.6	96.7A 7.4 82.0-111.0	95.1A 6.7 83.4-107.0	94.1A 6.0 79.6-105.2	87.1 5.2 76.8-99.9	24.5**
NASALWID	18.2A 1.8 14.4-21.7	17.5A 2.0 13.2-21.7	18.2A 2.2 12.8-22.3	17.1A 1.6 14.1-21.9	17.5A 2.0 15.0-23.2	17.7A 1.9 13.9-21.7	1.7
INTER	60.7A,B 2.7 56.5-66.8	61.3B 3.4 53.4-67.3	62.2B 2.8 57.0-67.7	60.1A,B 4.4 52.0-67.9	59.1A,B 3.3 53.3-67.4	59.4A 3.1 52.8-66.6	5.0**
ZYGOMA	109.1A 3.4 102.0-117.0	109.3A 3.4 103.0-119.0	110.1A 3.8 105.0-121.0	107.7A 5.7 99.0-119.0	107.0A 4.3 99.0-114.0	107.8A 4.2 97.0-116.0	2.9
PALATLEN	181.0A 6.2 168.0-197.0	177.7A 6.3 164.0-193.0	182.2A 7.2 168.0-194.0	178.0A 7.9 162.0-190.0	177.3A 6.6 165.0-194.0	168.5 7.6 154.0-188.0	29.0**
PALATWID	26.8A 1.6 23.5-30.0	26.7A 1.5 22.3-29.8	26.9A 1.7 23.9-29.8	26.9A 2.4 22.4-32.6	26.2A 1.6 23.4-29.1	26.4A 1.8 21.8-30.8	0.8
UPM2M3	79.2A 2.8 73.1-83.9	77.6A 3.5 70.2-85.9	78.9A 2.7 72.9-85.1	79.6A 3.7 71.9-87.4	79.1A 3.0 74.8-84.4	75.5 3.3 65.2-81.7	12.4**
LPM2M3	86.8B 3.2 79.1-94.4	86.6B 4.0 78.6-96.6	86.0A,B 3.5 78.5-92.3	85.7A,B 4.4 76.1-95.5	84.2A,B 2.9 78.5-89.9	83.5A 3.5 73.6-90.3	7.5**
M2M2	74.4B 2.2 68.6-81.3	74.5B 2.4 69.7-80.0	73.5A,B 2.7 68.9-78.0	73.3A,B 3.4 66.3-78.6	73.5A,B 2.5 69.2-79.3	72.4A 2.7 63.9-79.9	6.3**
DIASTEMA	72.7A 3.8 65.3-84.8	71.3A 4.5 61.5-83.0	73.8A 4.9 62.1-80.3	71.7A 4.9 63.6-80.8	70.0A,B 4.6 62.5-78.0	67.4B 4.6 58.6-79.6	12.6**
CRANBD	73.6A 2.5 67.9-79.7	74.3A 2.5 69.6-79.6	74.9A 2.8 70.2-81.4	72.7A 2.6 67.4-77.0	72.8A 1.8 69.4-75.8	73.1A 2.4 67.8-81.4	4.2**

Table 5. Continued.

Character	Northwestern Illinois (N=62)	Westcentral Illinois (N=71)	Eastcentral Illinois (N=26)	Effingham Co. Illinois (N=19)	Southcentral Illinois (N=20)	Southern Illinois (N=74)	F-value[a]
CRANHT	68.3A 2.3 63.7-78.3	68.1A 3.1 62.9-79.5	68.3A 1.8 64.5-71.6	67.5A 3.0 61.4-73.1	67.2A 2.4 62.3-71.7	67.9A 2.3 62.5-73.5	0.8
INCISIVE	37.8A,B 3.4 31.6-46.7	37.9B 3.1 31.5-46.1	38.5A,B 2.6 33.3-45.4	39.1B 3.2 33.2-45.9	37.8A,B 4.2 29.5-45.7	36.0A 3.5 27.4-45.7	4.7**
POSTPAL	75.5A 3.7 66.2-84.5	75.8A,B 4.0 66.3-86.2	78.7A,B 5.1 70.5-90.1	77.4B 3.9 71.4-84.6	75.1A,B 3.8 69.2-82.8	75.6A 3.3 67.3-84.2	3.5*
CONDYLAR	48.9A 2.2 43.7-53.9	49.4A,B 2.1 44.0-53.5	50.7A,B 2.1 46.8-55.0	49.4B 2.6 44.6-53.6	47.4A,C 2.3 41.5-51.3	47.1C 2.2 42.0-52.0	15.4**
ROSTRAL	39.4A 2.3 34.1-44.2	39.5A 2.6 33.4-45.5	40.4A 2.0 37.0-43.8	38.0A 2.7 34.1-43.4	38.6A 2.9 33.6-45.1	38.9A 2.2 34.2-44.3	3.1
MANDLEN	221.4A,B 6.3 208.0-240.0	219.0A 7.3 202.0-234.0	224.8B 7.6 212.0-237.0	221.8A,B 9.0 205.0-236.0	216.5A,C 7.7 206.0-234.0	211.0C 7.6 195.0-229.0	21.7**
MANDHT	108.4A 4.5 98.0-120.0	105.6A,B 5.2 95.0-118.0	107.0A,B 4.9 [illegible]-118.0	106.2A,B 5.1 95.0-115.0	107.1A,B 7.1 93.0-119.0	103.8B 5.3 94.0-114.0	5.9**

*$P<0.01$, **$P<0.001$
[a] 5,261-266 df

Table 6. Univariate comparisons of external measurements from adult female *Odocoileus virginianus* from three regions of Illinois. Data are mean, S.D., minimum, and maximum in millimeters. Like superscripts denote means not different by Tukey/Kramer multiple comparisons test ($P<0.01$).

Character	Northwestern Illinois (N=21-22)	Westcentral Illinois (N=26-27)	Southern Illinois (N=29-30)	F-Value^{a}
TOTAL	1720.0^{A} 60.1 1569.0-1820.0	1730.1^{A} 68.0 1588.0-1867.0	1609.0 80.0 1400.0-1740.0	25.3**
TAIL	226.0^{A} 23.0 181.0-265.0	240.3^{A} 23.3 195.0-289.0	223.0^{A} 31.0 170.0-290.0	3.4
FOOT	484.0^{A} 13.0 457.0-508.0	479.0^{A} 15.0 432.0-508.0	431.0 17.0 390.0-467.0	105.5**
EAR	161.0^{A} 6.3 147.0-170.0	157.1^{A} 11.0 127.0-177.0	155.0^{A} 8.0 136.0-170.0	3.0
METATARS	28.0^{A} 5.0 20.0-38.0	25.4^{A} 5.4 18.0-37.0	26.2^{A} 4.1 15.0-35.0	1.8
HGTSHLDR	960.0^{A} 50.0 830.0-1050.0	963.0^{A} 40.0 890.0-1040.0	894.0 41.0 830.0-970.0	24.2**

[**] $P<0.001$

[a] 2,75-76 df

Table 7. Classification resulting from a discriminant function analysis comparing 420 specimens of adult female *Odocoileus virginianus* from 6 regions of Illinois and specimens representing *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus*.

Actual Group	N	*macrourus*	*virginianus*	*borealis*	Predicted Group Membership Northwestern Illinois	Westcentral Illinois	Eastcentral Illinois	Southcentral Illinois	Effingham Co. Illinois
macrourus	65	30 46.2%	9 13.8%	12 18.5%	4 6.2%	3 4.6%	3 4.6%	4 6.2%	0 0.0%
virginianus	39	6 15.4%	29 74.4%	3 7.7%	1 2.6%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
borealis	71	11 15.5%	1 1.4%	39 54.9%	5 7.0%	11 15.5%	1 1.4%	1 1.4%	2 2.8%
NW Illinois	59	5 8.5%	0 0.0%	5 8.5%	36 61.0%	8 13.6%	2 3.4%	2 3.4%	1 1.7%
WC Illinois	63	4 6.3%	0 0.0%	13 20.6%	9 14.3%	34 54.0%	0 0.0%	0 0.0%	3 4.8%
EC Illinois	26	0 0.0%	0 0.0%	2 7.7%	5 19.2%	5 19.2%	13 50.0%	0 0.0%	1 3.8%
SC Illinois	19	4 10.5%	0 0.0%	3 15.8%	3 15.8%	0 0.0%	0 0.0%	8 42.1%	1 5.3%
Effingham Co.	19	2 10.5%	0 0.0%	7 36.8%	1 5.3%	1 5.3%	0 0.0%	2 10.5%	6 31.6%
Unknowns (S Illinois)	59	11 18.6%	1 1.7%	15 25.4%	10 16.9%	10 16.9%	4 6.8%	6 10.2%	2 3.4%

Table 8. Classification resulting from a discriminant function analysis comparing cranial ratios from 420 specimens of adult female *Odocoileus virginianus* from 6 regions of Illinois and specimens representing *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus*.

Actual Group	N	*macrourus*	*virginianus*	*borealis*	Predicted Group Membership Northwestern Illinois	Westcentral Illinois	Eastcentral Illinois	Southcentral Illinois	Effingham Co. Illinois
macrourus	65	32 49.2%	7 10.8%	12 18.5%	4 6.2%	5 7.7%	3 4.6%	2 3.1%	0 0.0%
virginianus	39	8 20.5%	19 48.7%	8 20.5%	2 5.1%	2 5.1%	0 0.0%	0 0.0%	0 0.0%
borealis	71	6 8.5%	4 5.6%	36 50.7%	9 12.7%	13 18.3%	1 1.4%	0 0.0%	2 2.8%
NW Illinois	59	5 8.5%	1 1.7%	5 8.5%	35 59.3%	8 13.6%	2 3.4%	2 3.4%	1 1.7%
WC Illinois	63	4 6.3%	1 1.6%	15 23.8%	8 12.7%	31 49.2%	1 1.6%	1 1.6%	2 3.2%
EC Illinois	26	3 11.5%	0 0.0%	3 11.5%	5 19.2%	5 19.2%	9 34.6%	0 0.0%	1 3.8%
SC Illinois	19	5 26.3%	0 0.0%	4 21.1%	4 21.1%	0 0.0%	2 10.5%	4 21.1%	0 0.0%
Effingham Co.	19	4 21.1%	0 0.0%	6 31.6%	2 10.5%	2 10.5%	0 0.0%	1 5.3%	4 21.1%
Unknowns (S Illinois)	59	4 6.8%	1 1.7%	9 15.3%	14 23.7%	18 30.5%	6 10.2%	5 8.5%	2 3.4%

Table 9. Classification resulting from a discriminant function analysis comparing 420 specimens of adult female Odocoileus virginianus from 6 regions of Illinois **and specimens** representing the large, small, and Missouri morphotypes.

Actual Group	N	Small	Large	Missouri	Predicted Group Membership Northwestern Illinois	Westcentral Illinois	Eastcentral Illinois	Southcentral Illinois	Effingham Co. Illinois
Small	56	48 85.7%	5 8.9%	0 0.0%	2 3.6%	1 1.8%	0 0.0%	0 0.0%	0 0.0%
Large	96	4 4.2%	65 67.7%	0 0.0%	5 5.2%	12 12.5%	3 3.1%	4 4.2%	3 3.1%
Missouri	23	1 4.3%	1 4.3%	16 69.6%	1 4.3%	3 13.0%	0 0.0%	1 4.3%	0 0.0%
NW Illinois	59	0 0.0%	10 16.9%	3 5.1%	33 55.9%	9 15.3%	2 3.4%	2 3.4%	0 0.0%
WC Illinois	63	0 0.0%	22 34.9%	0 0.0%	9 14.3%	30 47.6%	0 0.0%	0 0.0%	2 3.2%
EC Illinois	26	0 0.0%	4 15.4%	0 0.0%	4 15.4%	5 19.2%	12 46.2%	0 0.0%	1 3.8%
SC Illinois	19	0 0.0%	7 36.8%	2 10.5%	3 15.8%	0 0.0%	0 0.0%	7 36.8%	0 0.0%
Effingham Co.	19	0 0.0%	10 52.6%	0 0.0%	1 5.3%	1 5.3%	0 0.0%	2 10.5%	5 26.3%
Unknowns (S Illinois)	59	7 11.9%	18 30.5%	5 8.5%	11 18.6%	9 15.3%	3 5.1%	5 8.5%	1 1.7%

Table 10. Sheared principal component loadings for 20 cranial characters from 146 specimens of Odocoileus virginianus from 5 regions (first random set) of the eastern and midwestern United States.

Character	Size	Sheared PC-II	Sheared PC-III
GREATLEN	0.19	-0.15	-0.07
CONDYLO	0.18	-0.15	-0.07
NASALEN	0.25	-0.29	-0.07
NASALWID	0.45	0.78	0.09
INTER	0.22	-0.02	-0.07
ZYGOMA	0.17	0.00	-0.10
PALATLEN	0.20	-0.17	-0.04
PALATWID	0.24	-0.12	-0.13
UPM2M3	0.07	-0.18	0.00
LPM2M3	0.05	-0.17	0.06
M2M2	0.15	0.00	-0.09
DIASTEMA	0.33	-0.16	-0.12
CRANBD	0.16	0.02	-0.07
CRANHT	0.14	-0.02	-0.00
INCISIVE	0.33	-0.19	0.89
POSTPAL	0.14	-0.15	-0.19
CONDYLAR	0.14	-0.09	-0.15
ROSTRAL	0.30	0.15	-0.21
MANDLEN	0.18	-0.14	-0.10
MANDHT	0.22	-0.16	-0.13
% of variance	52.0	12.0	8.0

Table 11. Sheared principal component loadings for 20 cranial characters from 175 specimens of Odocoileus virginianus from 5 regions (second random set) of the eastern and midwestern United States.

Character	Size	Sheared PC-II	Sheared PC-III
GREATLEN	0.15	-0.19	-0.06
CONDYLO	0.15	-0.21	-0.07
NASALEN	0.20	-0.38	-0.12
NASALWID	0.62	0.63	0.02
INTER	0.22	-0.01	-0.08
ZYGOMA	0.16	-0.02	-0.06
PALATLEN	0.18	-0.24	-0.02
PALATWID	0.25	-0.03	-0.03
UPM2M3	0.02	-0.13	-0.16
LPM2M3	0.02	-0.12	-0.24
M2M2	0.14	-0.04	-0.15
DIASTEMA	0.26	-0.30	0.16
CRANBD	0.10	-0.02	-0.10
CRANHT	0.12	0.01	-0.12
INCISIVE	0.32	-0.18	0.79
POSTPAL	0.11	-0.09	-0.17
CONDYLAR	0.07	-0.23	-0.25
ROSTRAL	0.29	0.09	-0.23
MANDLEN	0.15	-0.19	-0.07
MANDHT	0.18	-0.12	-0.18
% of variance	41.0	15.0	9.0

Table 12. Multiple and partial correlations (partialling all other IVs) resulting from the regression of latitude (LAT), soil fertillity (SOIL), % forest (FOR), and hunter success (HUNTER) on eviscerated mass of white-tailed deer from Illinois.

Age/Sex	R	Model R^2	pr^2	
Fawn Males	0.74, $F_{4,74}= 22.4^*$	0.55	LAT	0.12
			SOIL	0.01
			FOR	0.08
			HUNTER	0.07
Yearling Males	0.62, $F_{4,74}= 12.0^*$	0.39	LAT	0.04
			SOIL	0.00
			FOR	0.04
			HUNTER	0.19
Adult Males	0.60, $F_{4,74}= 10.3^*$	0.36	LAT	0.01
			SOIL	0.01
			FOR	0.03
			HUNTER	0.13

Table 12. Continued.

Age/Sex	R	Model R^2	pr^2	
Fawn Females	0.78, $F_{4,74}= 28.6^{*}$	0.61	LAT	0.20
			SOIL	0.00
			FOR	0.09
			HUNTER	0.18
Yearling Females	0.75, $F_{4,74}= 23.3^{*}$	0.56	LAT	0.20
			SOIL	0.00
			FOR	0.04
			HUNTER	0.19
Adult Females	0.71, $F_{4,74}= 24.4^{*}$	0.51	LAT	0.08
			SOIL	0.00
			FOR	0.13
			HUNTER	0.13

$^{*}P<0.0001$

Table 13. Results of analysis of residuals resulting from the regression of latitude (LAT), soil fertility (SOIL), % forest (FOR), and hunter success (HUNTER) on eviscerated mass of white-tailed deer from three regions of Illinois.

Age/Sex	ANOVA	Contrast[a]		
Fawn Females	$F_{2,76}= 8.69^{**}$	Northern vs. Central	$F_{1,47}= 12.84$	$P= 0.001$
		Southern vs. Central	$F_{1,51}= 12.55$	$P= 0.001$
		Southern vs. Northern	$F_{1,45}= 0.03$	$P= 0.852$
Yearling Females	$F_{2,76}= 3.54^{*}$	Northern vs. Central	$F_{1,47}= 4.82$	$P= 0.031$
		Southern vs. Central	$F_{1,51}= 5.51$	$P= 0.022$
		Southern vs. Northern	$F_{1,45}= 0.00$	$P= 0.958$
Adult Females	$F_{2,76}= 6.13^{**}$	Northern vs. Central	$F_{1,47}= 8.51$	$P= 0.005$
		Southern vs. Central	$F_{1,51}= 9.38$	$P= 0.003$
		Southern vs. Northern	$F_{1,45}= 0.00$	$P= 0.990$

Table 13. Continued.

Age/Sex	ANOVA	Contrast		
Fawn Males	$F_{2,76}= 8.68^{***}$			
		Northern vs. Central	$F_{1,47}= 12.46$	$P= 0.001$
		Southern vs. Central	$F_{1,51}= 12.92$	$P= 0.001$
		Southern vs. Northern	$F_{1,45}= 0.01$	$P= 0.932$
Yearling Males	$F_{2,76}= 6.99^{**}$			
		Northern vs. Central	$F_{1,47}= 8.72$	$P= 0.004$
		Southern vs. Central	$F_{1,51}= 11.55$	$P= 0.001$
		Southern vs. Northern	$F_{1,45}= 0.00$	$P= 0.767$
Adult Males	$F_{2,76}= 7.96^{***}$			
		Northern vs. Central	$F_{1,47}= 11.17$	$P= 0.001$
		Southern vs. Central	$F_{1,51}= 12.10$	$P= 0.001$
		Southern vs. Northern	$F_{1,45}= 0.00$	$P= 0.990$

[*] $P< 0.05$, [**] $P< 0.01$, [***] $P< 0.001$

[a] for pairwise contrasts alpha= $^{alpha}/_{k}= {}^{0.05}/_{3}= 0.017$

Table 14. Multiple and partial correlations (partialling all other IVs) resulting from the regression of latitude (LAT), soil fertility (SOIL), % forested (FOR), and hunter success (HUNTER) on mean eviscerated mass of white-tailed deer from three regions of Illinois.

Sex/Age	Region	R	Model R^2	pr2
Fawn Males	Northern	0.81, F= 8.27**	0.65	LAT 0.64 SOIL 0.37 FOR 0.24 HUNTER 0.04
	Central	0.50, F= 1.81	0.23	
	Southern	0.85, F= 14.11***	0.72	LAT 0.43 SOIL 0.00 FOR 0.08 HUNTER 0.04
Yearling Males	Northern	0.79, F= 7.6**	0.63	LAT 0.41 SOIL 0.01 FOR 0.12 HUNTER 0.00
	Central	0.52, F= 2.23	0.27	

Table 14. Continued.

Sex/Age	Region	R	Model R^2	pr2	
Yearling Males	Southern	0.82, F= 11.25***	0.67	LAT	0.41
				SOIL	0.01
				FOR	0.02
				HUNTER	0.14
Adult Males	Northern	0.72, F= 4.7**	0.52	LAT	0.47
				SOIL	0.01
				FOR	0.01
				HUNTER	0.04
	Central	0.39, F= 1.1	0.15		
	Southern	0.79, F= 8.9***	0.62	LAT	0.35
				SOIL	0.02
				FOR	0.05
				HUNTER	0.04
Fawn Females	Northern	0.66, F= 3.5*	0.44	LAT	0.42
				SOIL	0.24
				FOR	0.11
				HUNTER	0.03
	Central	0.53, F= 2.37	0.28		

Table 14. Continued.

Sex/Age	Region	R	Model R^2	pr2
Fawn Females	Southern	0.90, F= 23.11***	0.81	LAT 0.47 SOIL 0.07 FOR 0.23 HUNTER 0.20
Yearling Females	Northern	0.50, F= 1.52	0.25	
	Central	0.42, F= 1.33	0.18	
	Southern	0.85, F= 14.34***	0.72	LAT 0.49 SOIL 0.04 FOR 0.00 HUNTER 0.00
Adult Females	Northern	0.74, F= 5.3**	0.54	LAT 0.51 SOIL 0.23 FOR 0.24 HUNTER 0.01
	Central	0.41, F= 1.3	0.17	

Table 14. Continued.

Sex/Age	Region	R	Model R^2	pr2
Adult Females	Southern	0.90, F= 24.1***	0.81	LAT 0.42 SOIL 0.00 FOR 0.24 HUNTER 0.19

*P<0.05; **P<0.01; ***P<0.001

Table 15. Correlations between latitude and meteorological parameters[a].

Region		Snow	Grow	Temp
Northern Illinois	LAT	0.87^{***}	-0.87^{***}	-0.59^{**}
Central Illinois	LAT	0.82^{***}	-0.41^{*}	-0.85^{***}
Southern Illinois	LAT	0.83^{***}	-0.68^{***}	-0.60^{***}

[a] Snow= mean annual snowfall; Grow= length of growing season; Temp= mean January temperature.

$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

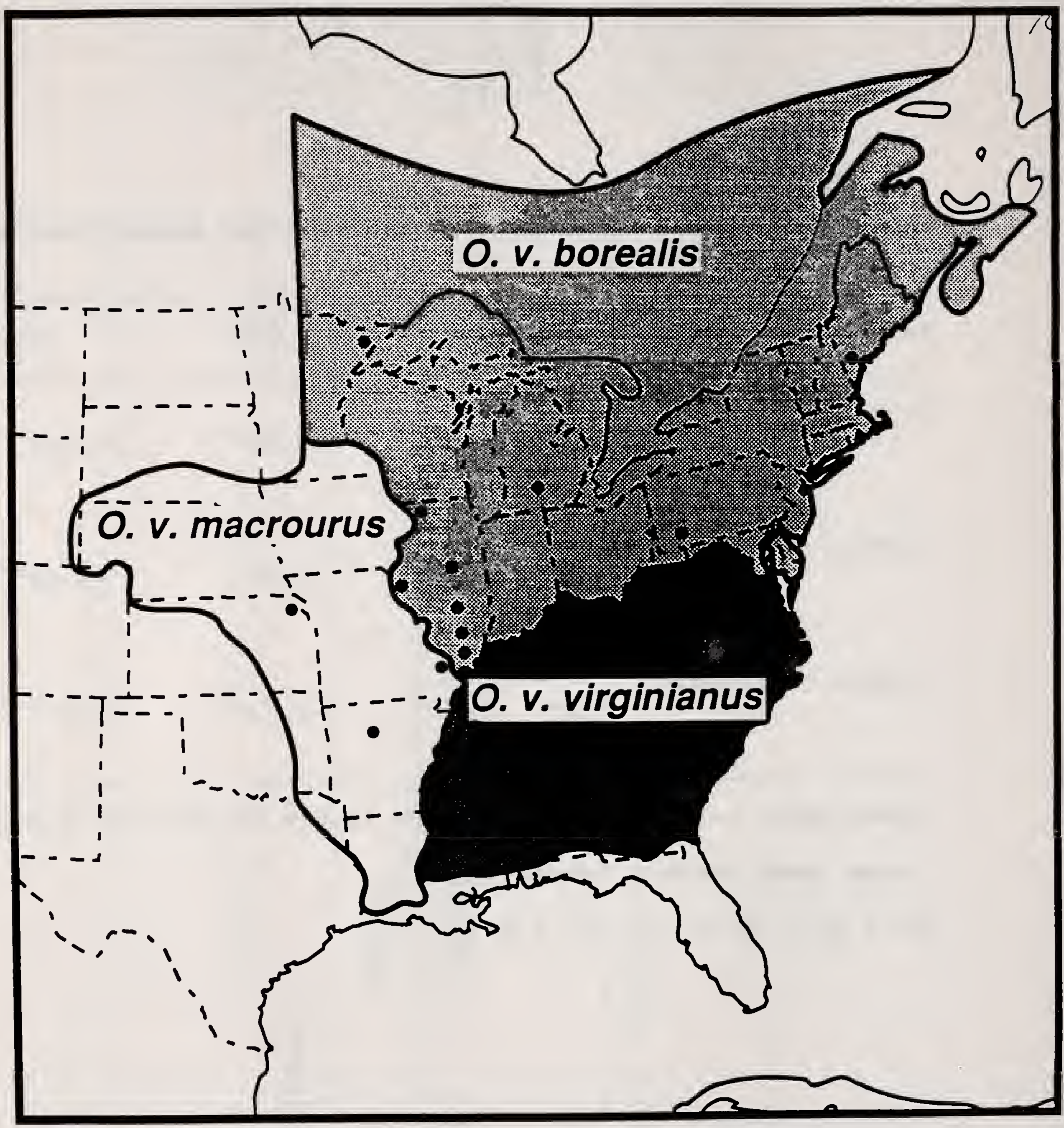

Fig. 1. Map depicting currently-accepted ranges of *Odocoileus virginianus borealis*, *O. v. macrourus*, and *O. v. virginianus*. Dots represent collection localities.

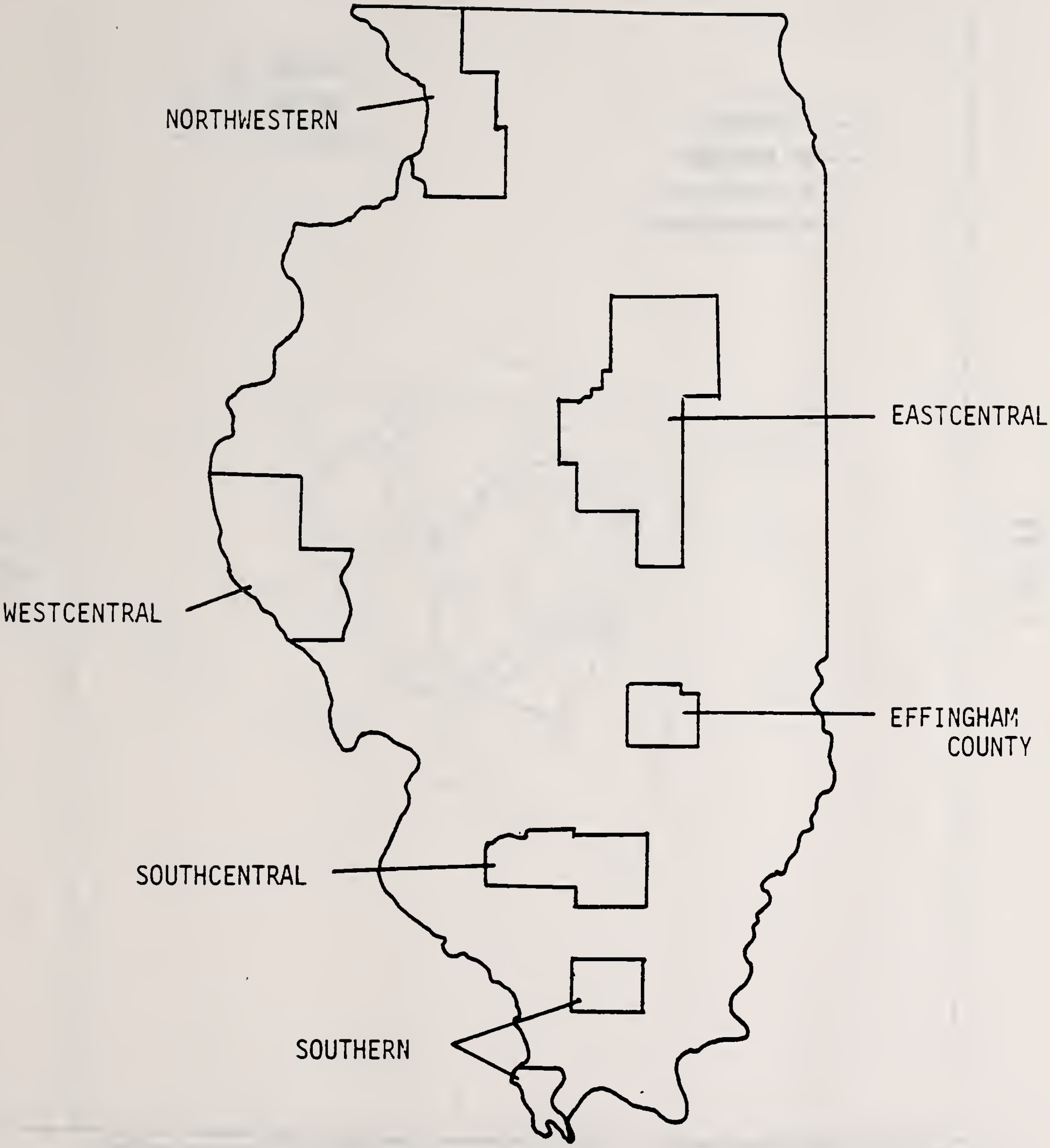

Fig. 2. Collection localities within Illinois.

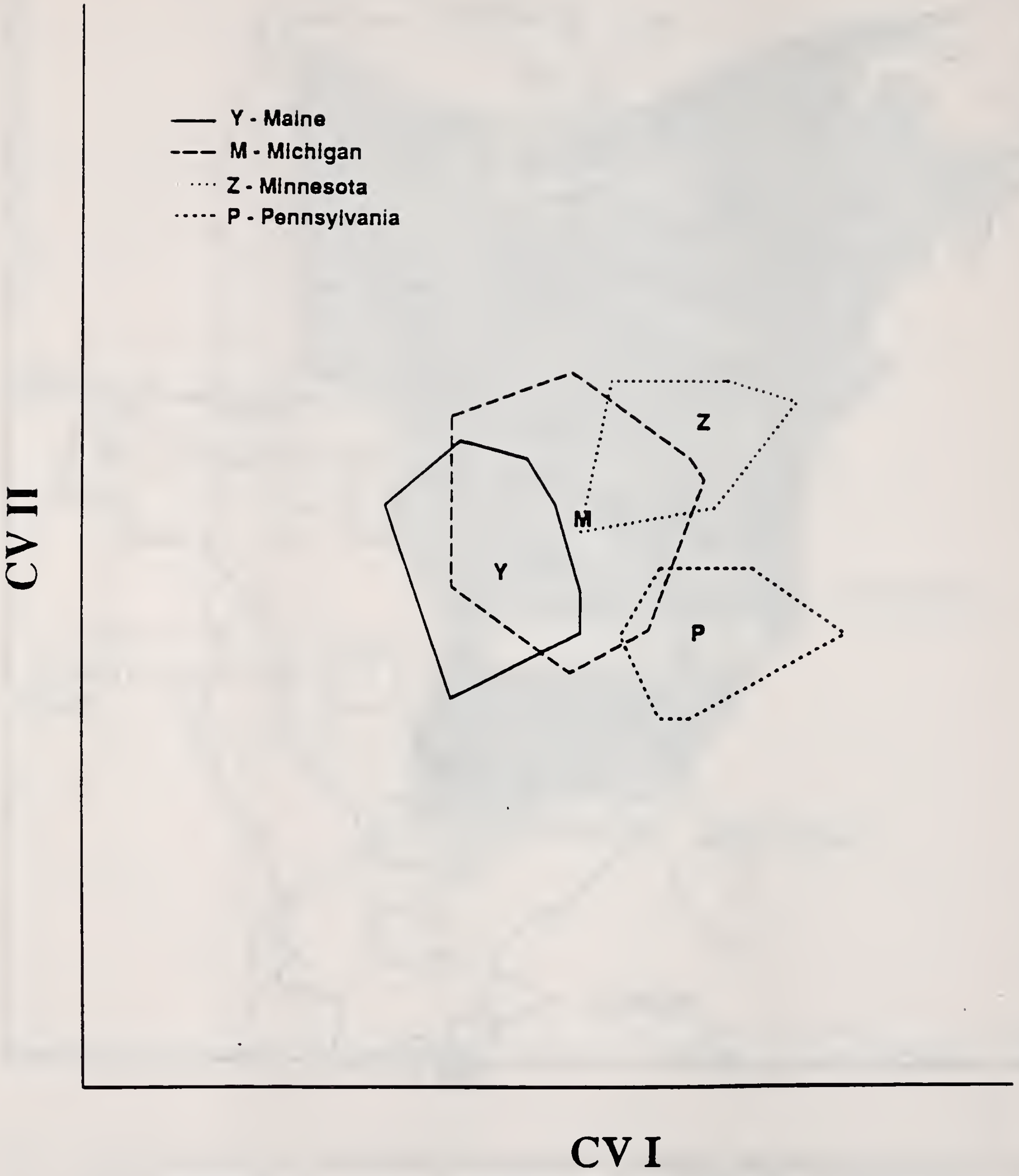

Fig. 3. Plot of canonical-variates scores derived from a series of 20 cranial measurements from specimens of Odocoileus virginianus from 4 regions of the northern United States. Polygons enclose individual scores and letters represent group centroids.

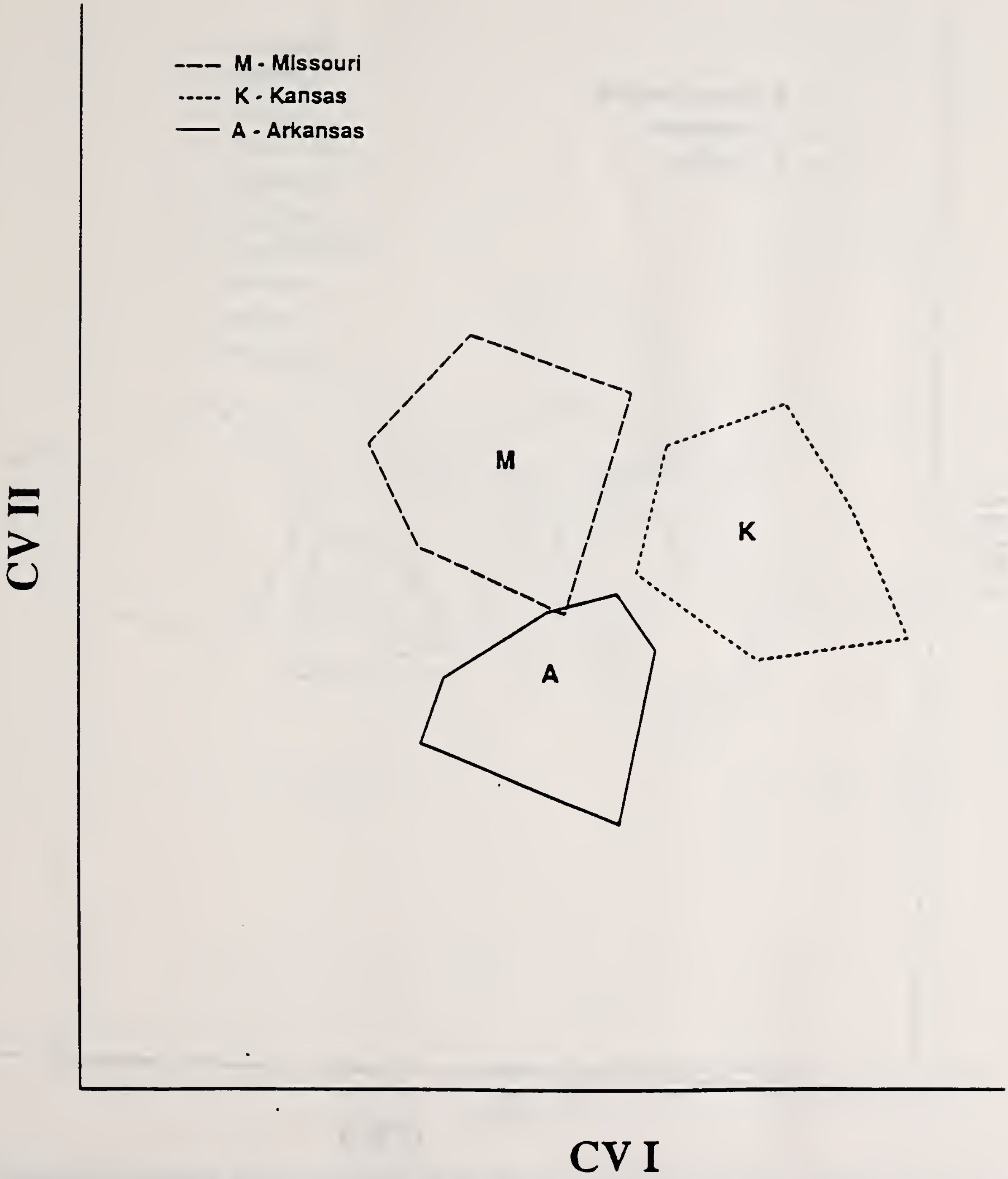

Fig. 4. Plot of canonical-variates scores derived from a series of 20 cranial measurements from specimens of Odocoileus virginianus macrourus from 3 regions of the central United States. Polygons enclose individual scores and letters represent group centroids.

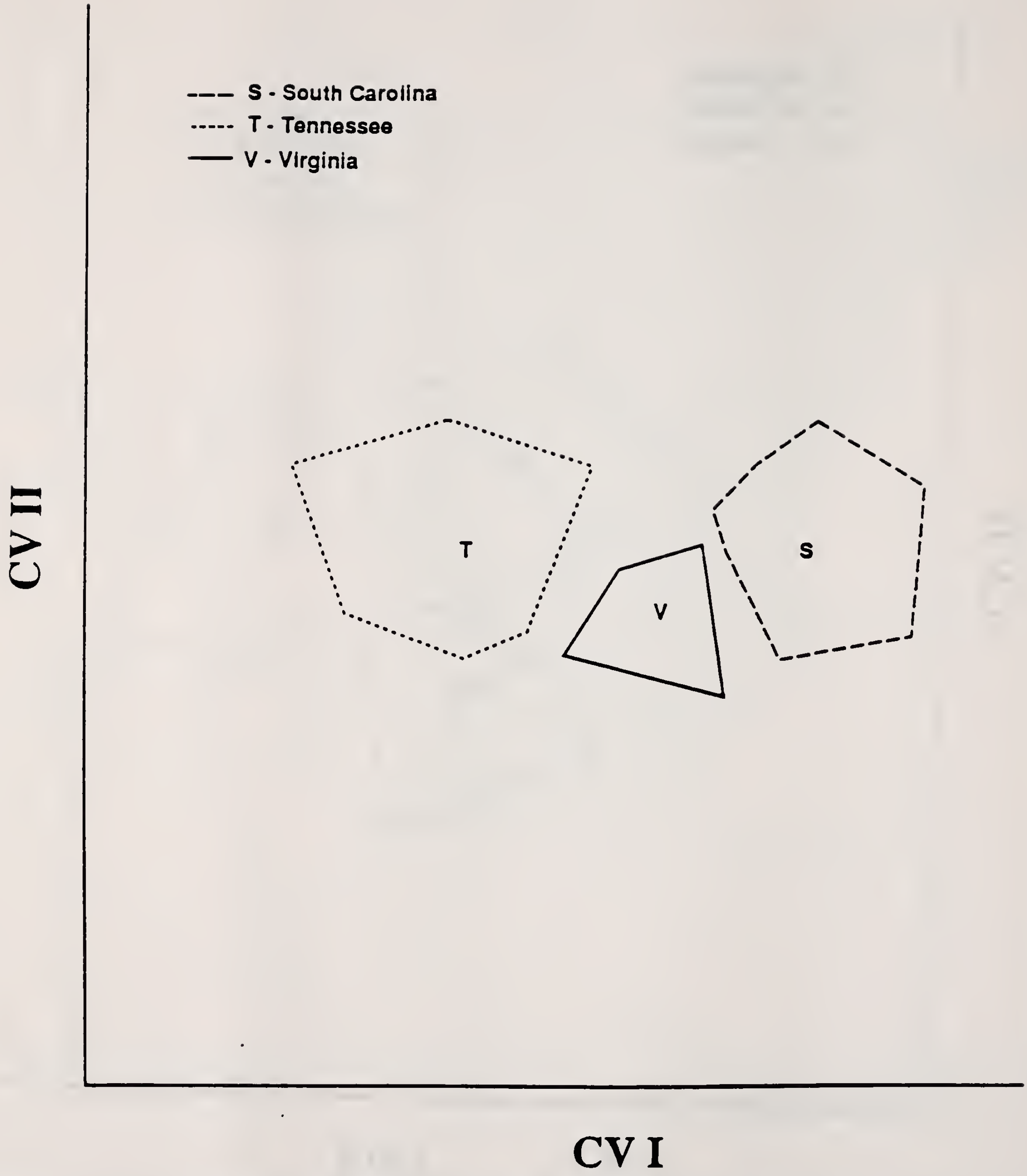

Fig. 5. Plot of canonical-variates scores derived from a series of 20 cranial measurements from specimens of _Odocoileus_ _virginianus_ _virginianus_ from 3 regions of the southeastern United States. Polygons enclose individual scores and letters represent group centroids.

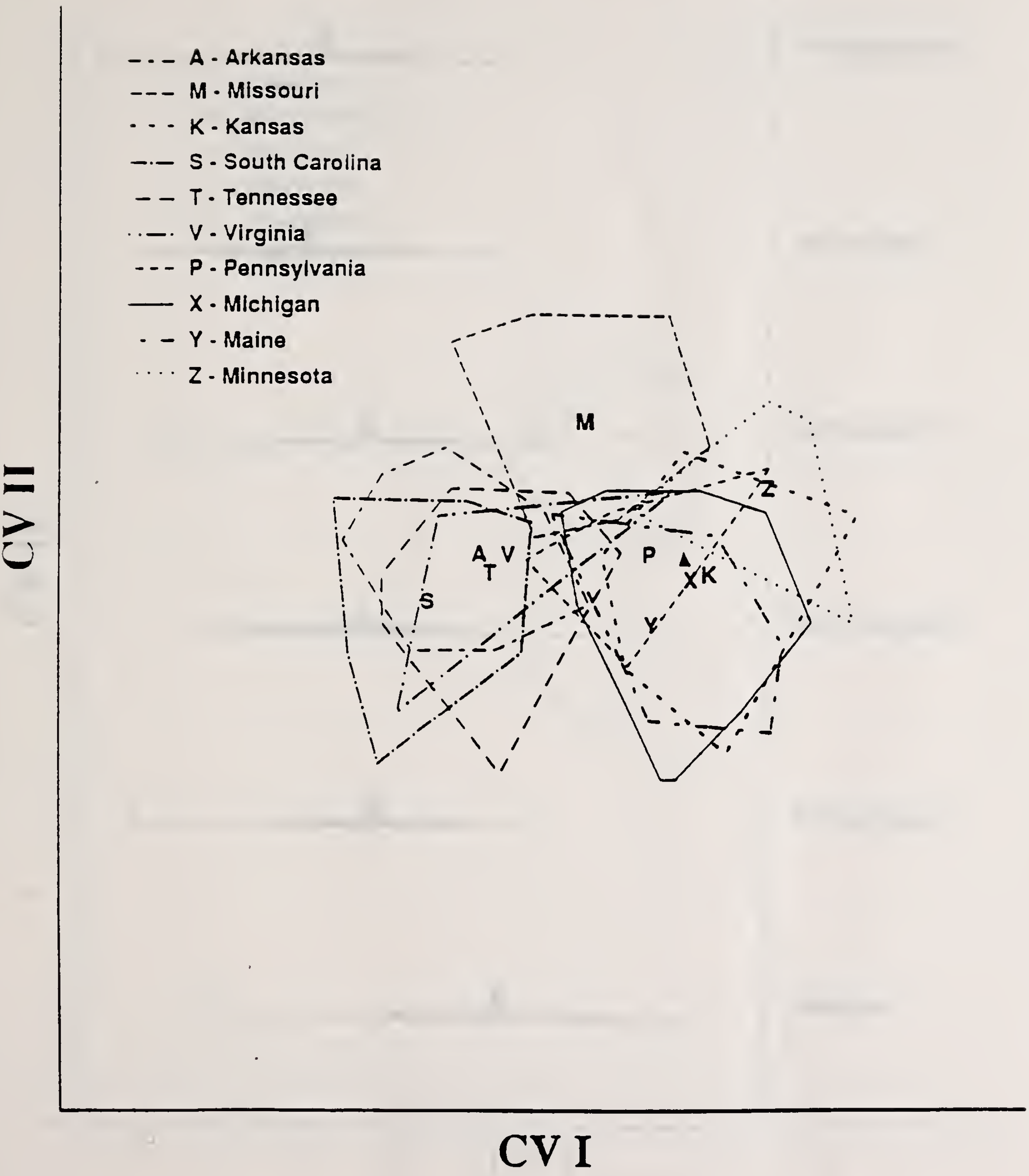

Fig. 6. Plot of canonical-variates scores derived from a series of 20 cranial measurements from specimens of Odocoileus virginianus from 10 regions of the eastern and midwestern United States. Polygons enclose individual scores and letters represent group centroids. The triangle represents 1 specimen from Arkansas.

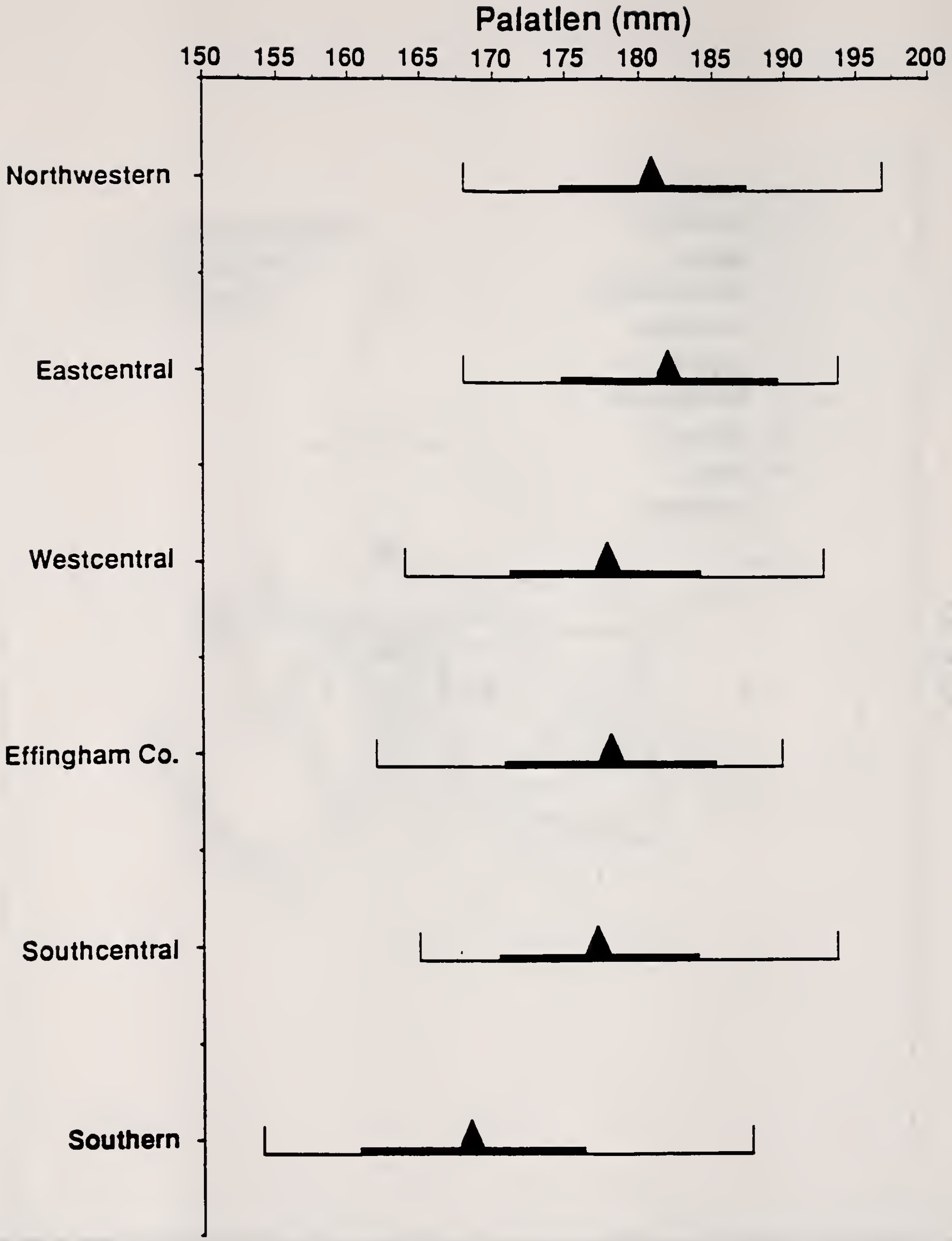

Fig. 7. Geographic variation in PALATLEN in specimens of Odocoileus virginianus from 6 regions of Illinois. Means are indicated by solid triangles, ranges by open boxes, and 1 standard deviation above and below mean by solid bars.

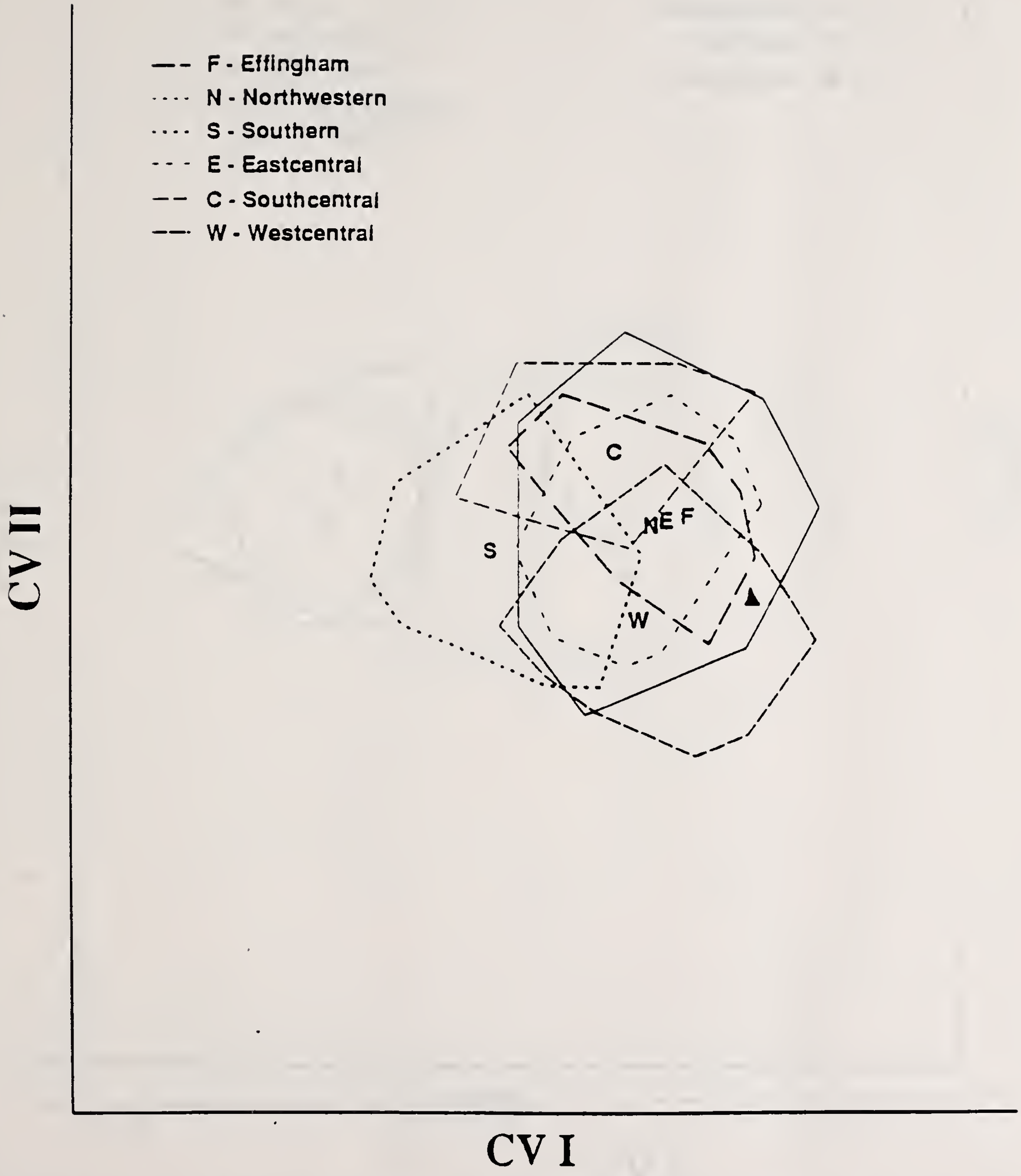

Fig. 8. Plot of canonical-variates scores derived from a series of 20 cranial measurements from specimens of Odocoileus virginianus from 6 regions of Illinois. Polygons enclose individual scores and letters represent group centroids. The triangle represents 1 specimen from southern Illinois.

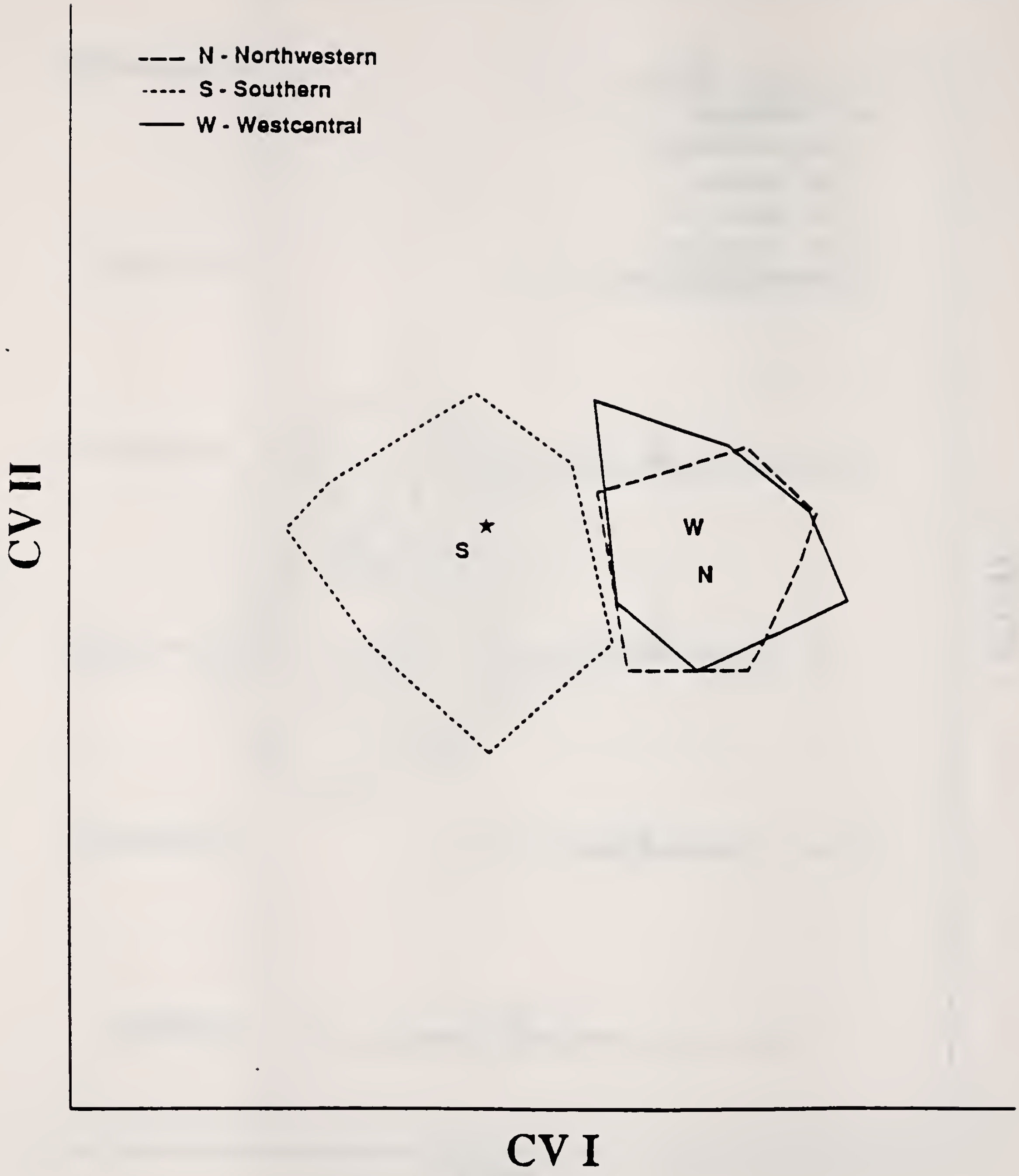

Fig. 9. Plot of canonical-variates scores derived from a series of 6 external measurements from specimens of Odocoileus virginianus from 3 regions of Illinois. Polygons enclose individual scores and letters represent group centroids. The star represents 1 specimen from westcentral Illinois.

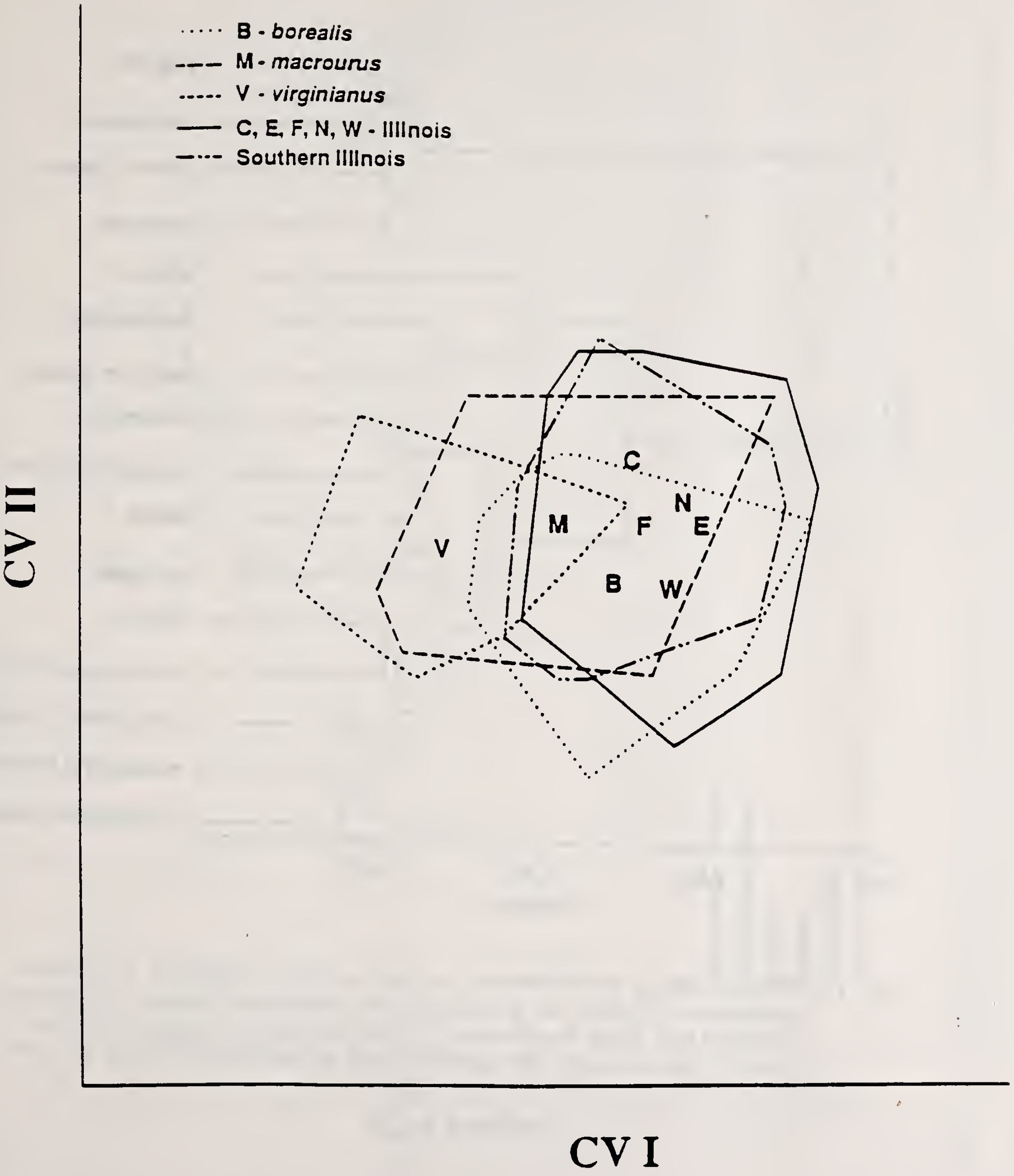

Fig 10. Plot of canonical-variates scores derived from a series of 20 cranial measurements from specimens of Odocoileus virginianus from 6 regions of Illinois and specimens representing O. v. borealis, O. v. macrourus, and O. v. virginianus. Polygons enclose individual scores and letters represent group centroids.

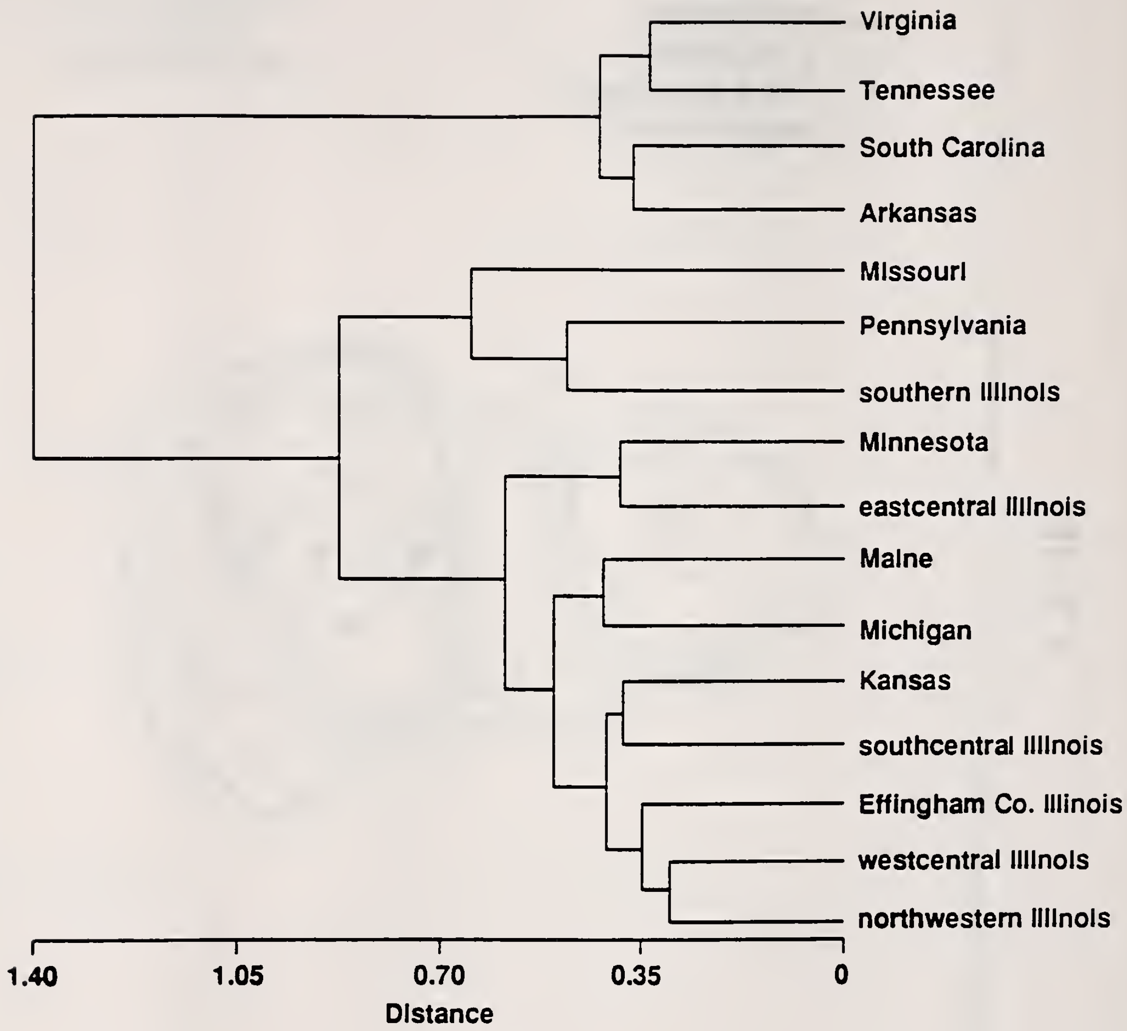

Fig. 11. Phenogram of morphometric relationships based on a cluster analysis (UPGMA) of standardized character means of 20 cranial characters from samples of *Odocoileus virginianus* from 16 localities within the eastern and midwestern United States.

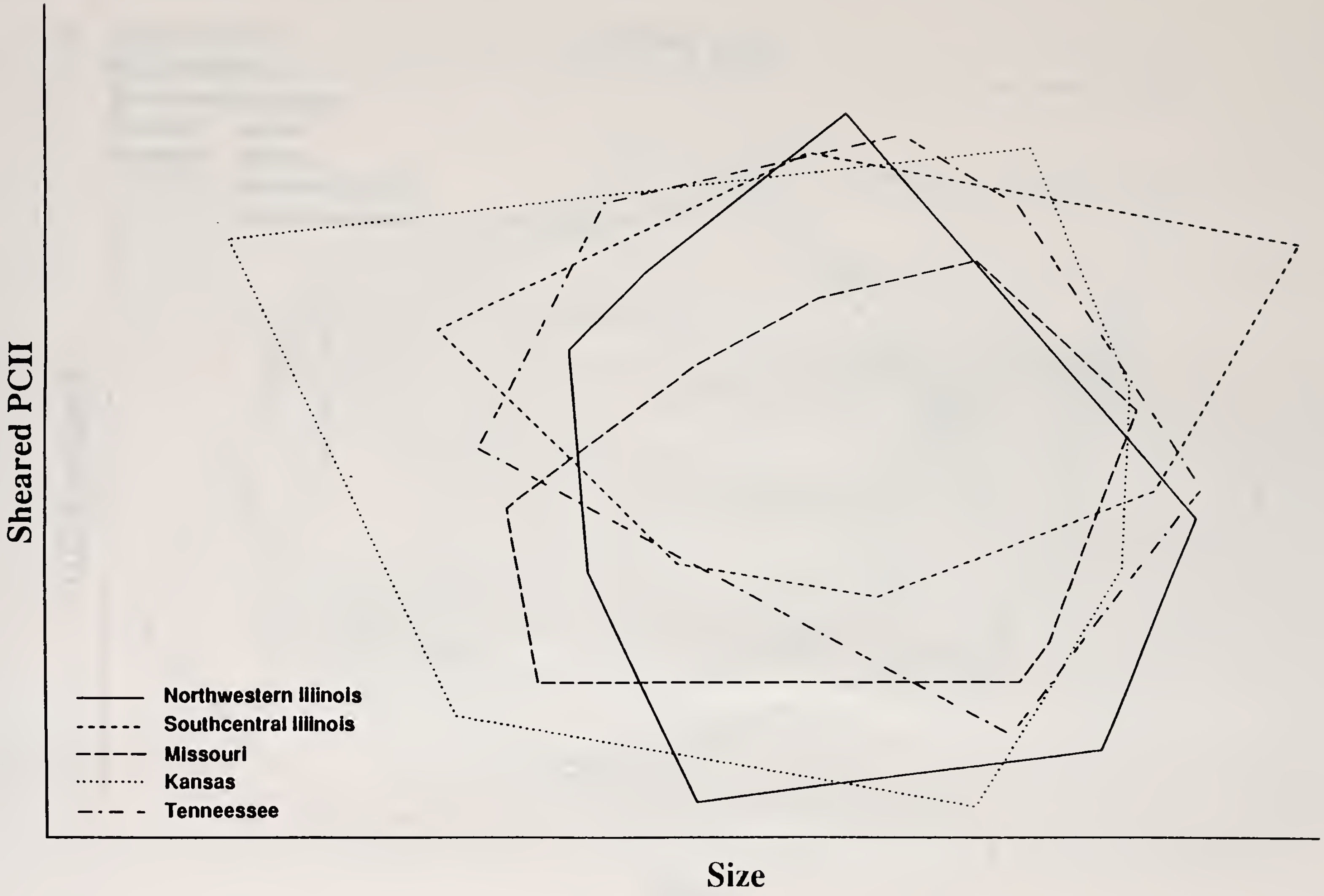

Fig. 12. Sheared principal components axes I (size) and II for the first random set of localities. Polygons enclose individual scores for a given region.

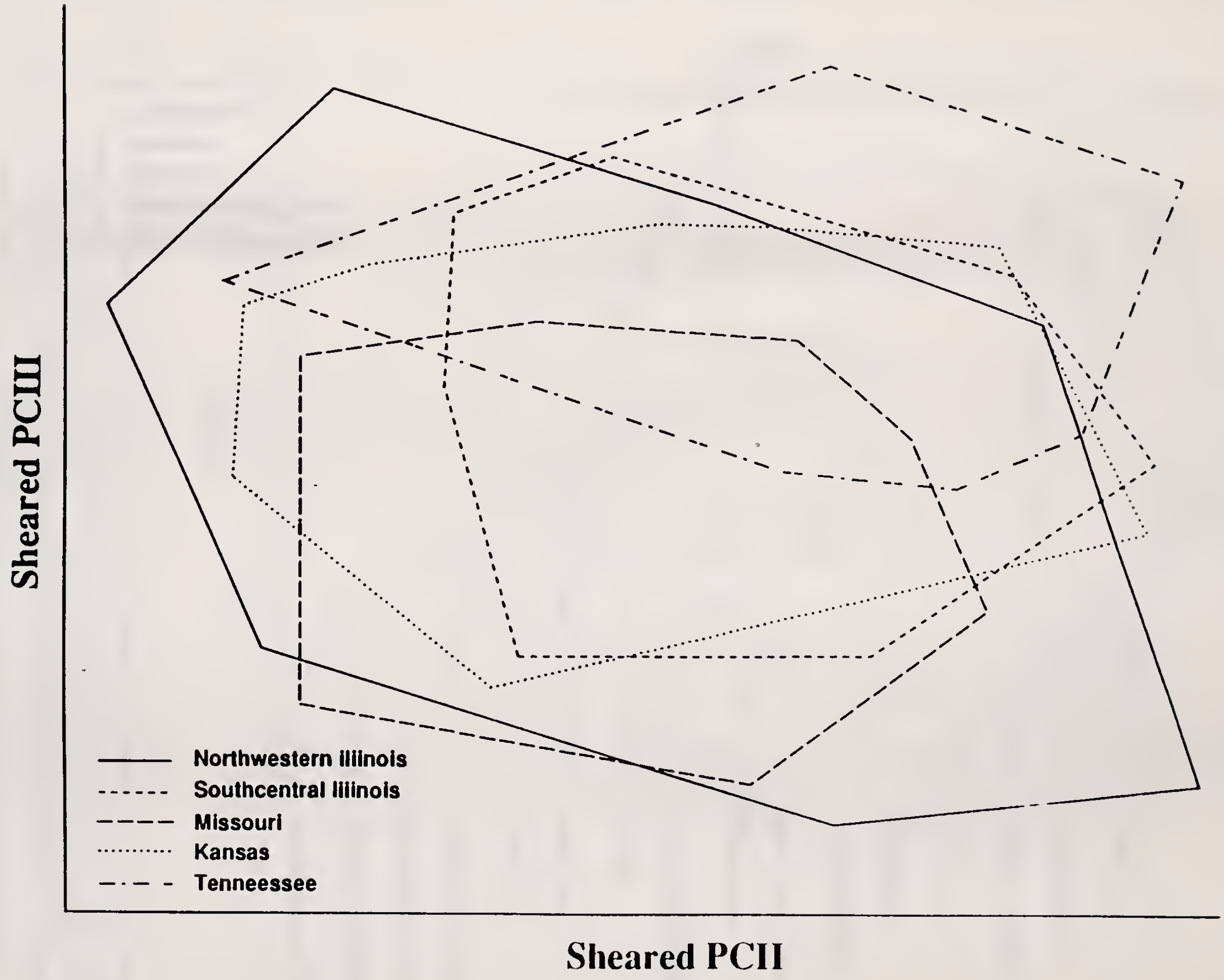

Fig. 13. Sheared principal components axes II and III for the first random set of localities. Polygons enclose individual scores for a given region.

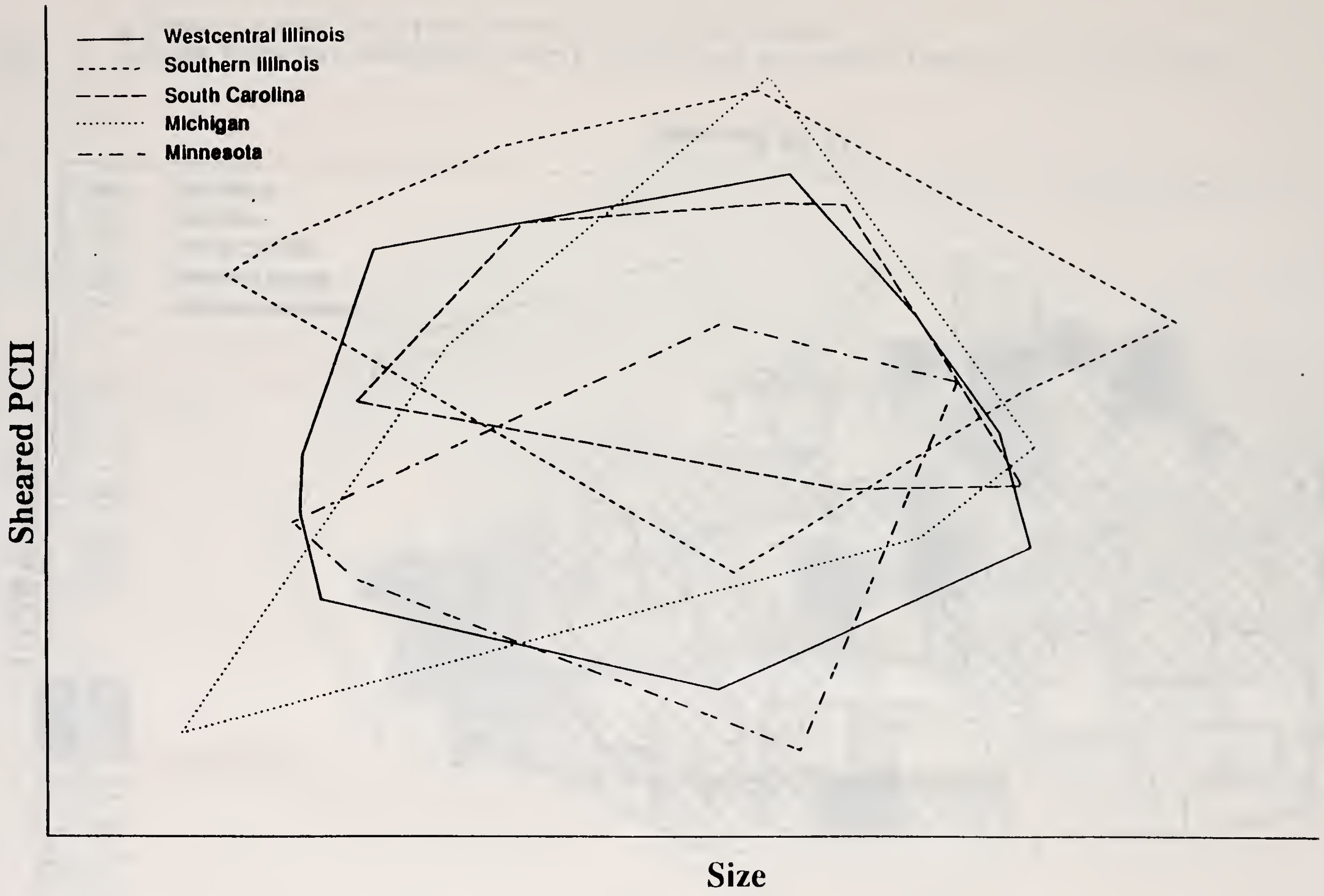

Fig. 14. Sheared principal component axes I (size) and II for the second random set of localities. Polygons enclose individual scores for a given region.

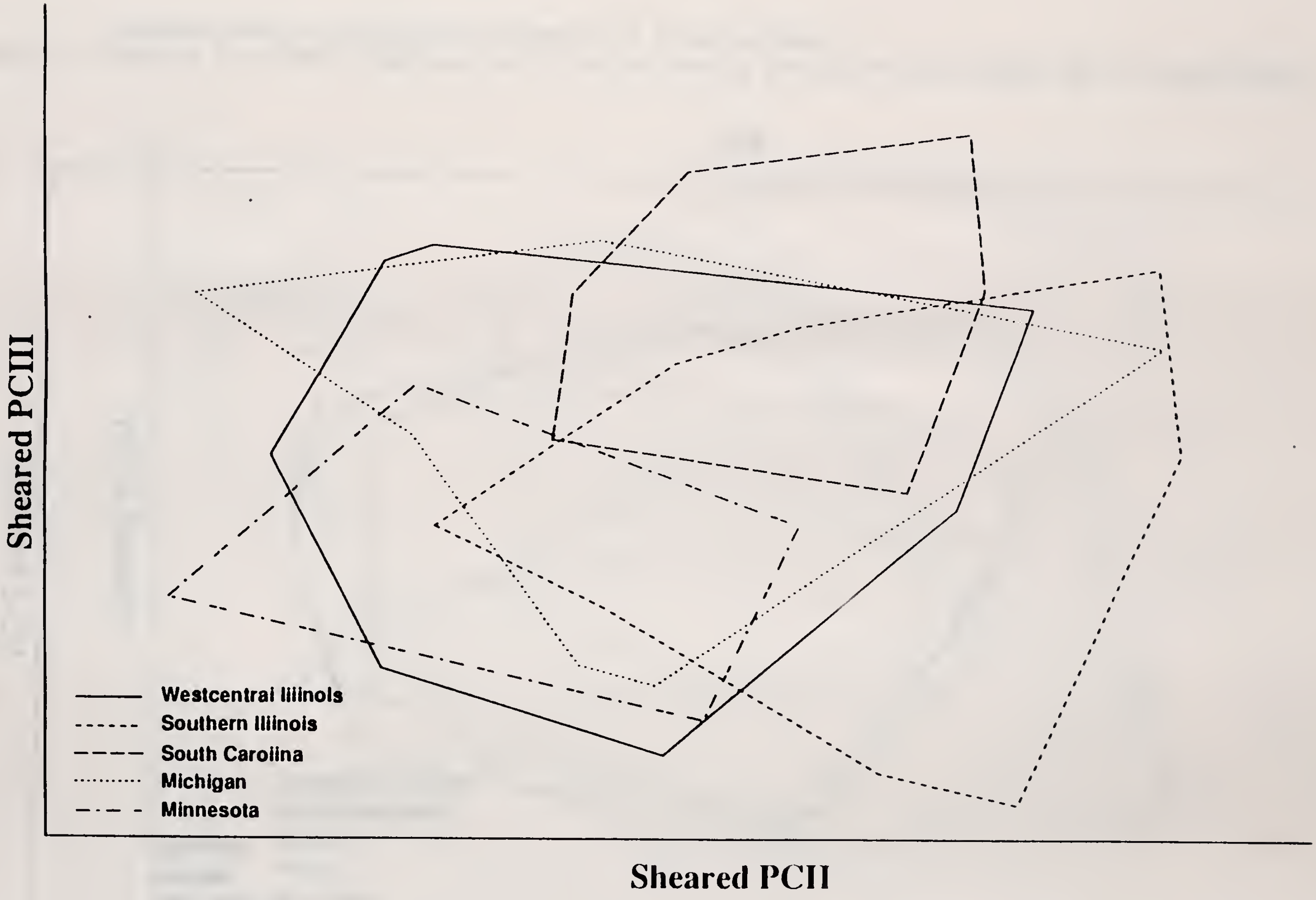

Fig. 15. Sheared principal component axes II and III for the second random set of localities. Polygons enclose individual scores for a given region.

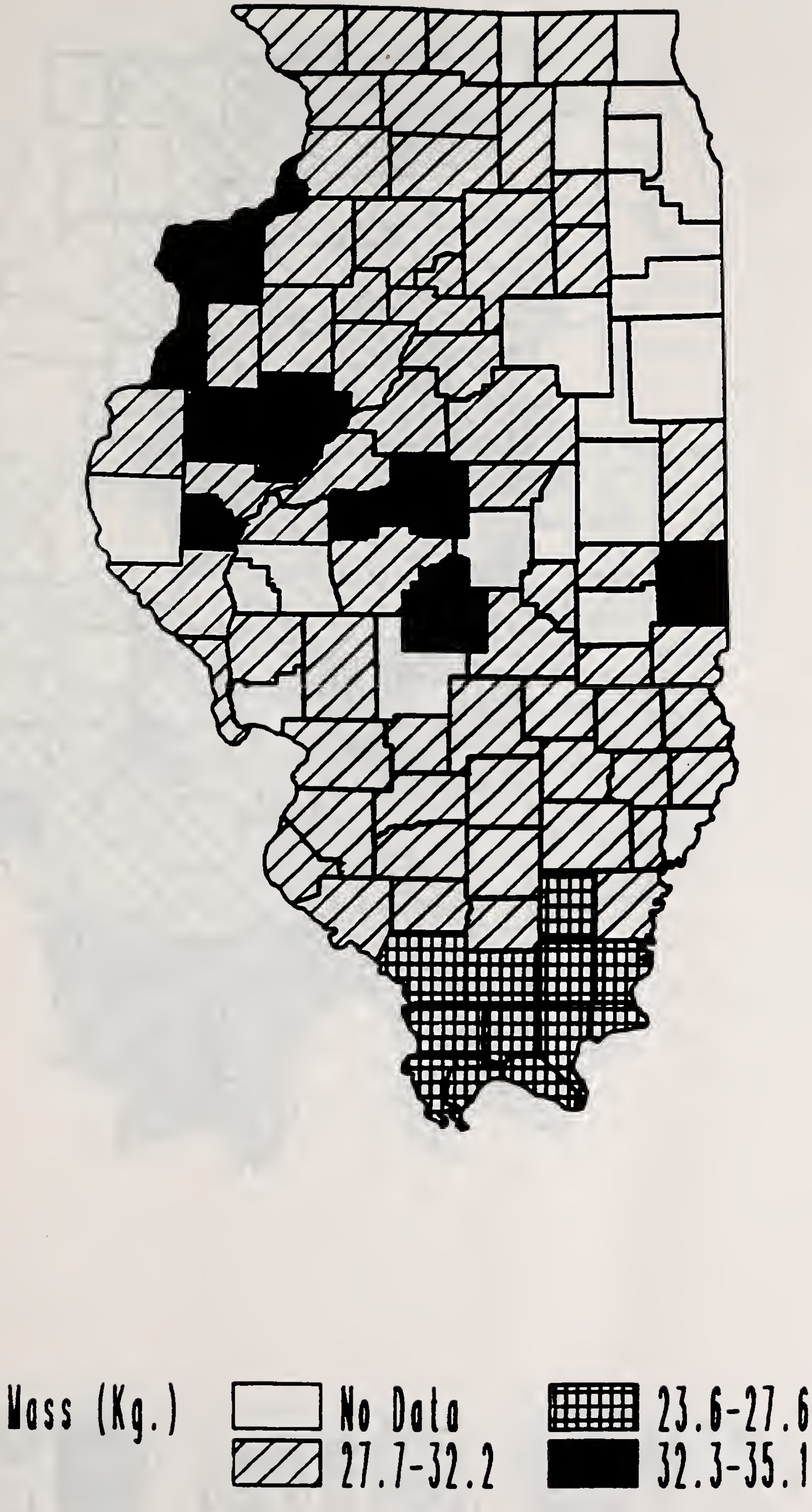

Fig. 16. Map depicting geographic distribution of mean eviscerated mass of female white-tailed deer fawns.

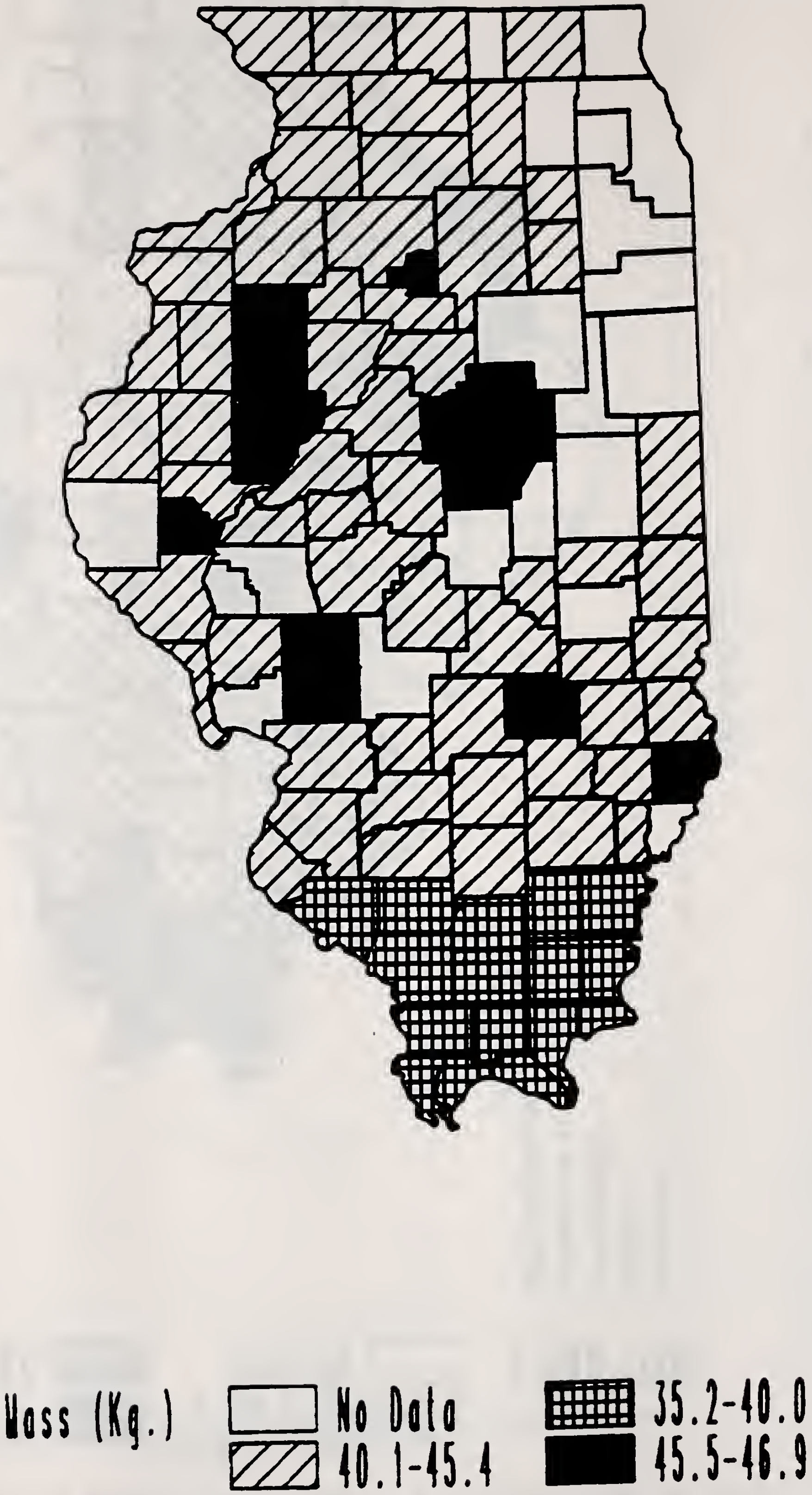

Fig. 17. Map depicting geographic distribution of mean eviscerated mass of yearling female white-tailed deer.

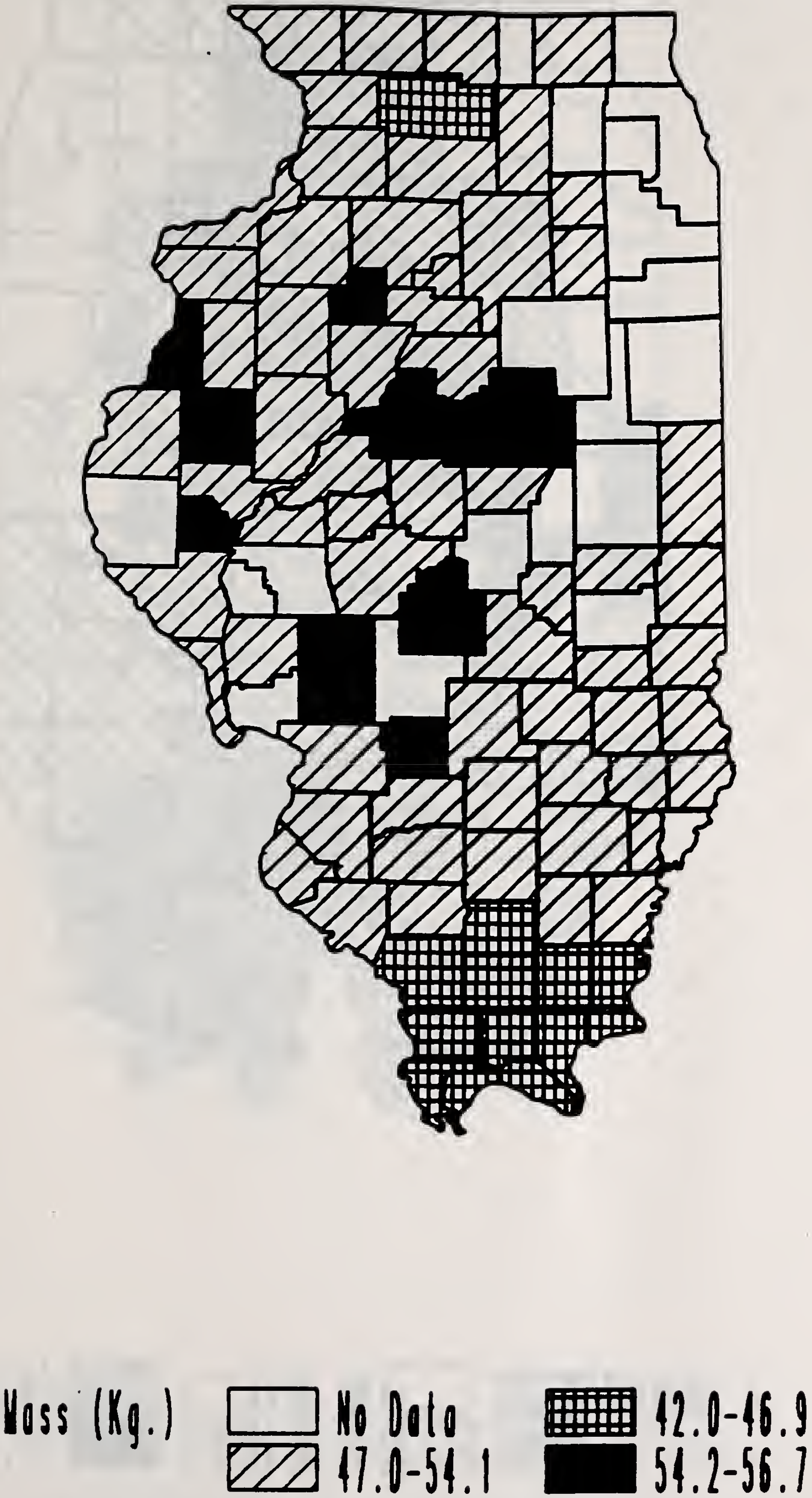

Fig. 18. Map depicting geographic distribution of mean eviscerated mass of adult female white-tailed deer.

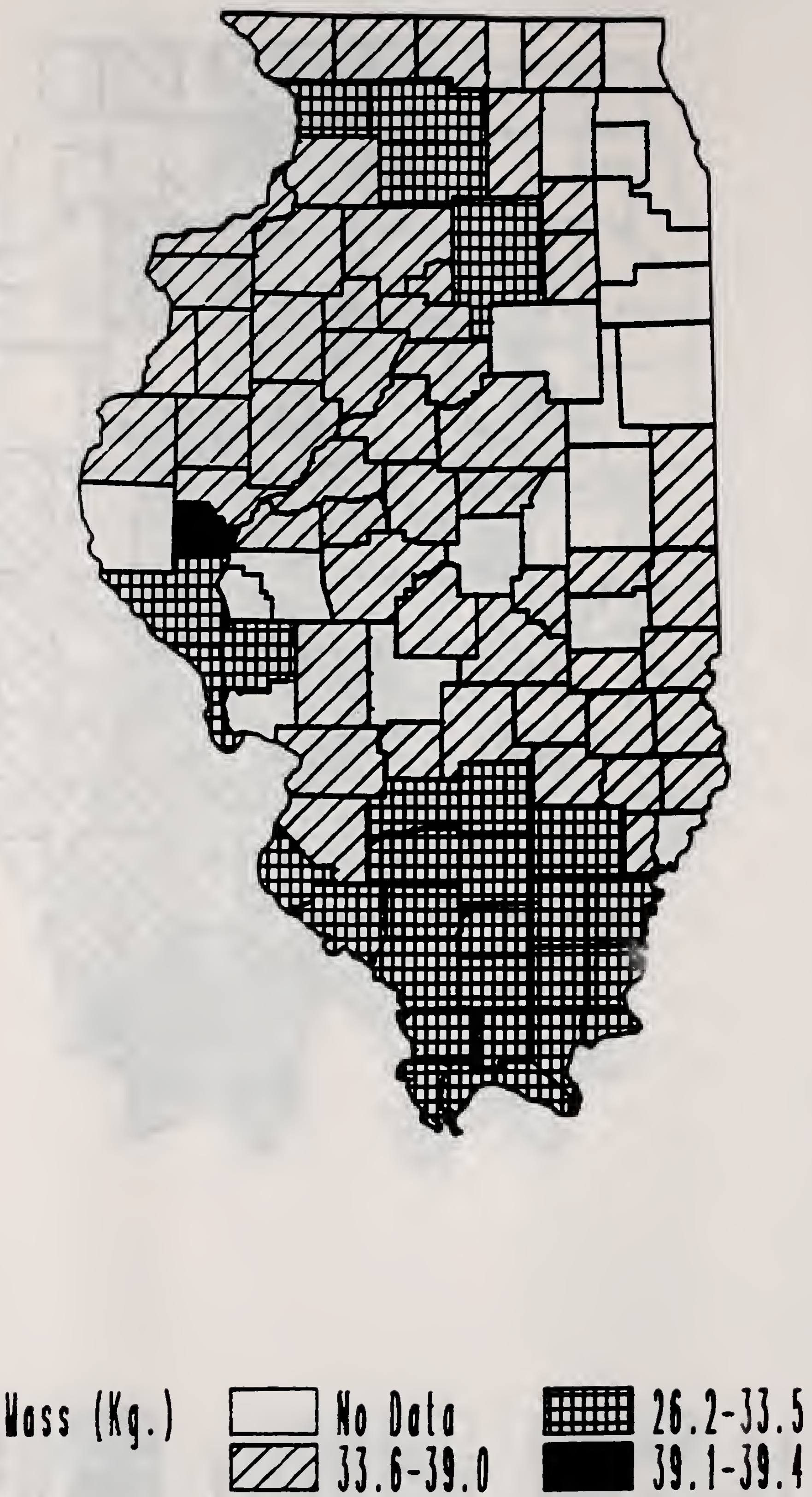

Fig. 19. Map depicting geographic distribution of mean eviscerated mass of male white-tailed deer fawns.

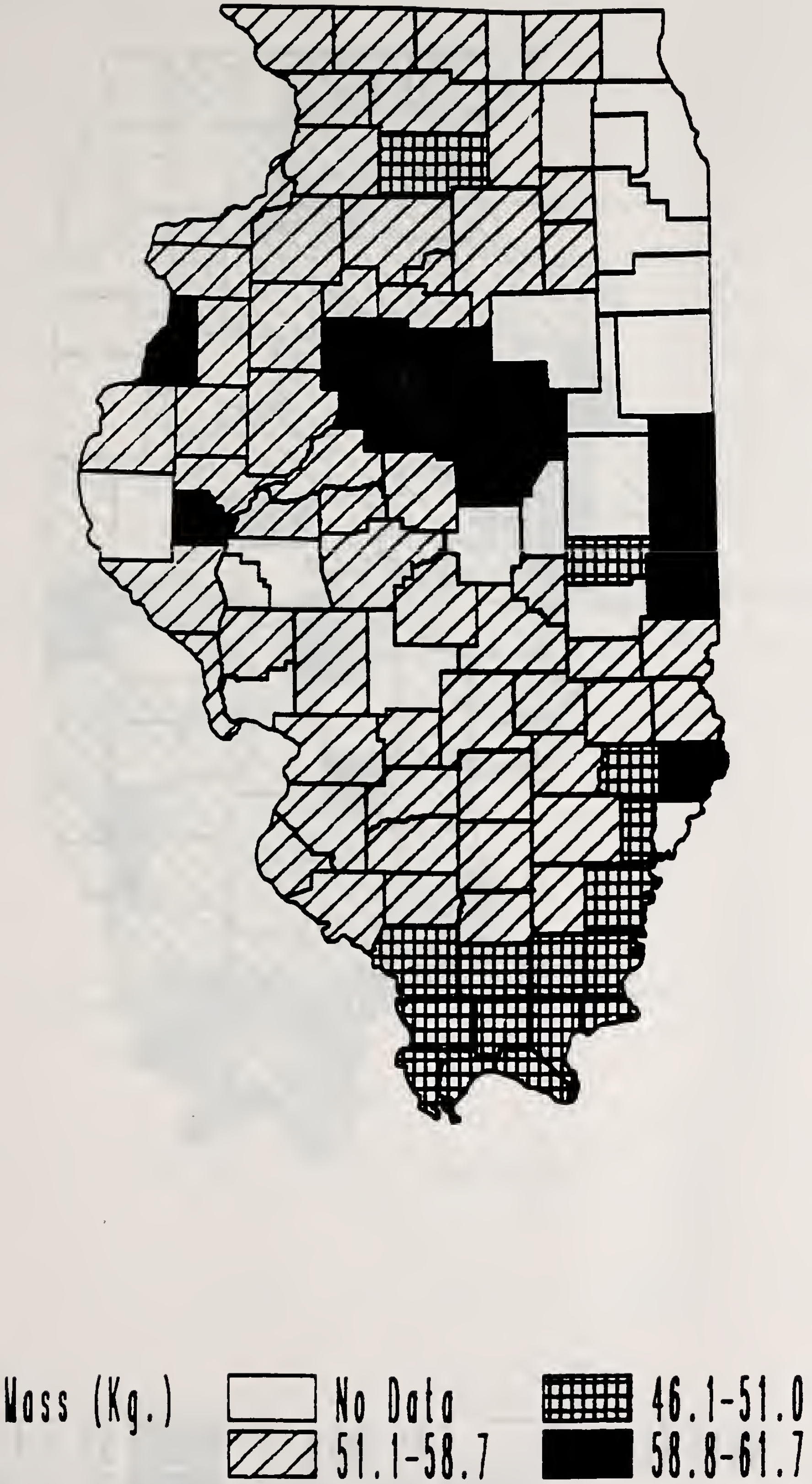

Fig. 20. Map depicting geographic distribution of mean eviscerated mass of yearling male white-tailed deer fawns.

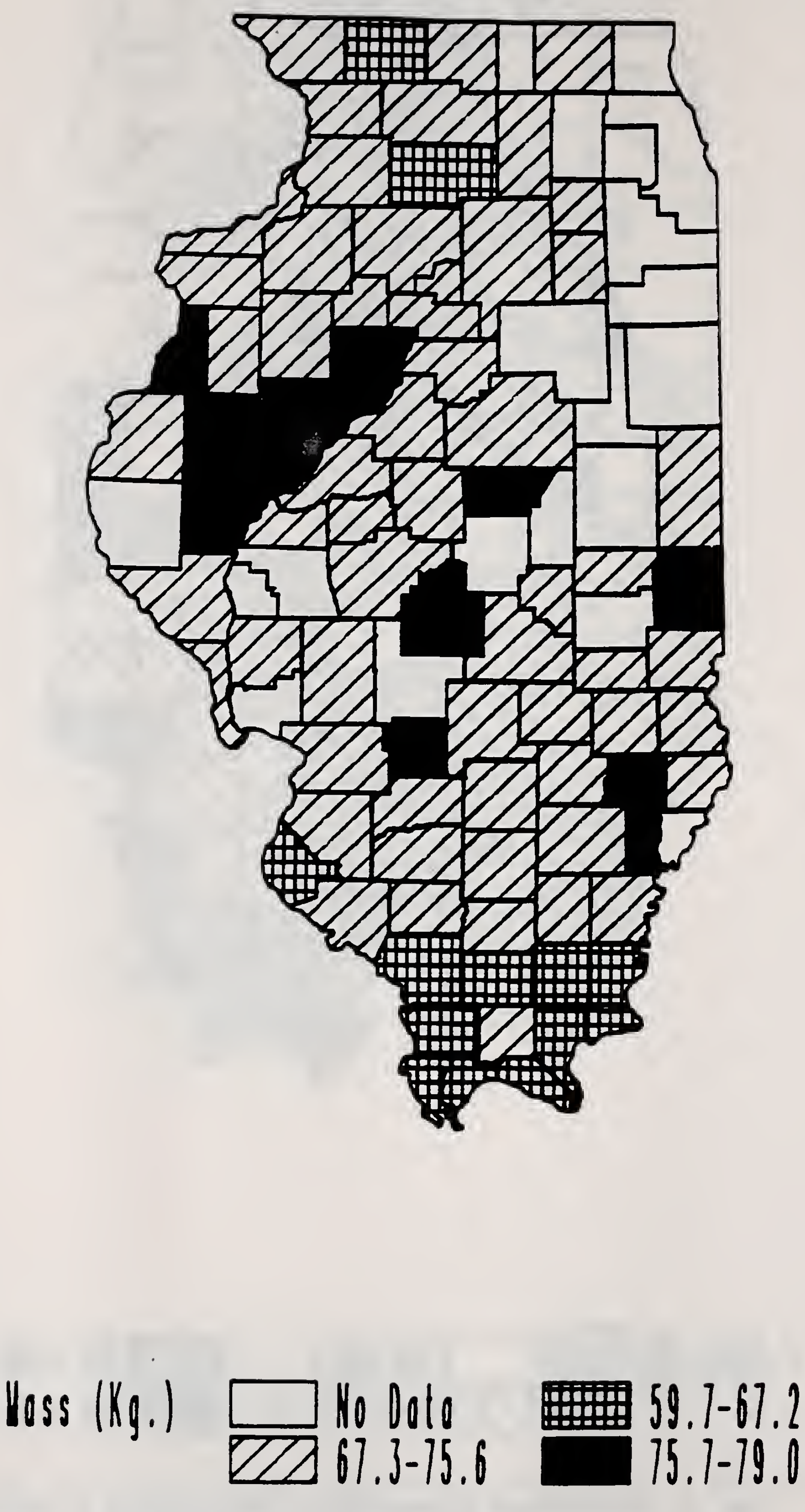

Fig. 21. Map depicting geographic distribution of mean eviscerated mass of adult male white-tailed deer.

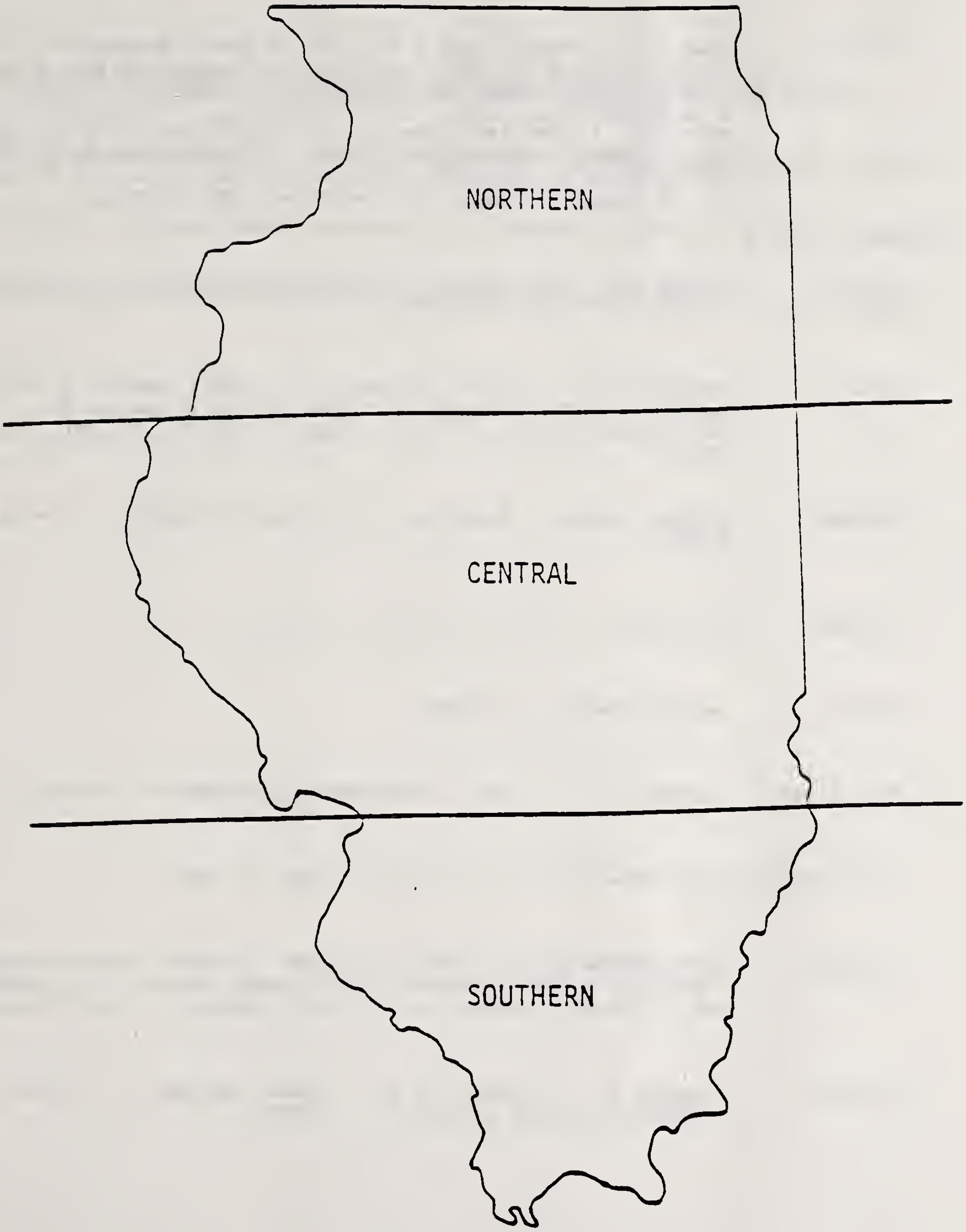

Fig. 22. Regional divisions of Illinois used in the analysis of geographic variation in eviscerated mass of white-tailed deer.

APPENDIX A

Collection localities, number of specimens, and abbreviations of museums housing specimens.

Arkansas:	Drew Co., 1 (CWRL); Pope Co., Ho[illegible]nd NWR, 12 (CWRL); Prairie Co., 3 (CWRL); Van Buren Co., 1 (CWRL); unknown (prev[illegible] counties or Franklin Co.), 2 (CWRL).
Illinois:	Adams Co., 16 (CWRL); Adams or Pike Co., 30 (CWRL); Alexander Co., Horseshoe Lake Conservation Area, 14 (CWRL), Horseshoe Lake Conservation Area or Crab Orchard National Wildlife Refuge (Williamson Co.), 4 (CWRL); Carroll Co., 11 (CWRL), Carroll or Jo Daviess Co., 4 (CWRL); Carroll, Jo Daviess, or Whiteside Co., 37 (CWRL); Dewitt Co., 3 (CWRL); Effingham Co., 19 (CWRL); Jefferson Co., 8 (CWRL); Jo Daviess Co., 10 (CWRL); Livingston Co., 4 (CWRL); Livingston, McLean, or Piatt Co., 11 (CWRL); McLean Co., 6 (CWRL); Piatt Co., 2 (CWRL); Pike Co., 25 (CWRL); Washington Co., 12 (CWRL); Williamson Co., Crab Orchard NWR, 56 (CWRL).
Kansas:	Douglas Co., 1 (KU); Douglas, Jefferson, or Leavenworth Co., 24 (CWRL); Johnson Co., 1 (KU); Leavenworth Co., 3 (KU).
Maine:	Androscoggin Co., 1 (CWRL); Kennebec Co., 2 (CWRL), Oaklawn, 1 (CWRL); Knox Co., Appleton, 1 (CWRL); Penobscot Co., Orono, 1 (CWRL); Somerset Co., 1 (CWRL); Waldo Co., 2 (CWRL), Belfast, 1 (CWRL), Brooks, 1; York Co., 3 (CWRL); southern Maine, 3 (CWRL).
Michigan:	Clinton, Ingham, or Shawassee Co., 24 (CWRL); Livingston Co., George Reserve, 6 (UMMZ).
Minnesota:	Cook, Itasca, Lake, or St. Louis Co., 34 (CWRL).
Missouri:	Cape Girardeau Co., 27 (CWRL).
Pennsylvania:	Westmorland Co., 9 (CMNH), Rachelwood Wildlife Research Preserve, 17 (CWRL).
South Carolina:	Aiken/Barnwell Cos., Savannah River Plant, 17 (CWRL).
Tennessee:	Carroll/Henderson Cos., Natchez Trace WMA, 1 (MSUMZ); Fayette/Hardeman Cos., Ames Plantation, 2 (MSUMZ); Hardeman Co., 3 (MSUMZ); Haywood Co., 1 (MSUMZ), Hatchie NWR, 11 (MSUMZ); Henderson Co., 1 (MSUMZ); Shelby Co., Shelby Forest WMA, 4 (MSUMZ).
Virginia:	Allegheny Co., 1 (USNM); Bath Co., 1 (USNM); New Kent Co., 1 (USNM); Richmond Co., 1 (USNM); Shenandoah National Park, 1 (USNM).

JOB D. **Analysis and Report**

Objective: To integrate published data and findings from these studies into management recommendations.

This objective has been met through annual reporting of findings to Illinois Department of Conservation staff in Quarterly and Annual Performance Reports and this Project Final Report. Original data and copies of all reports are on file at the Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale, Carbondale, IL 62901.

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